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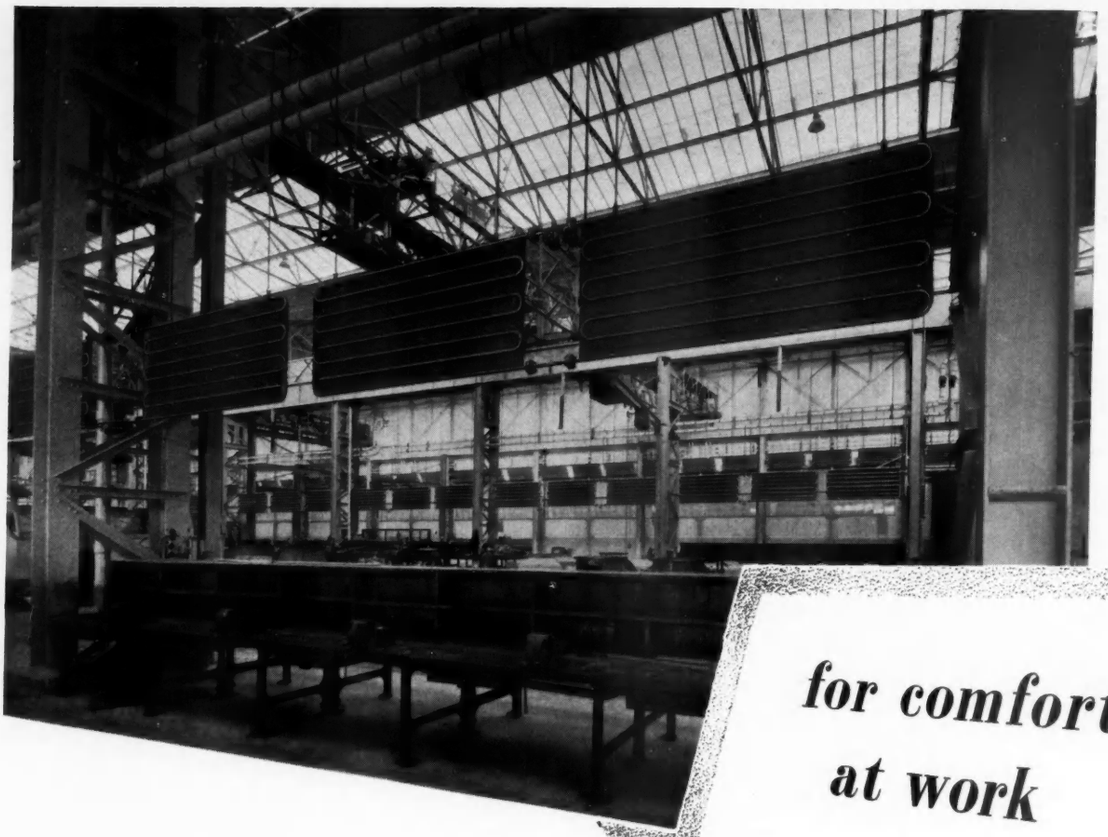

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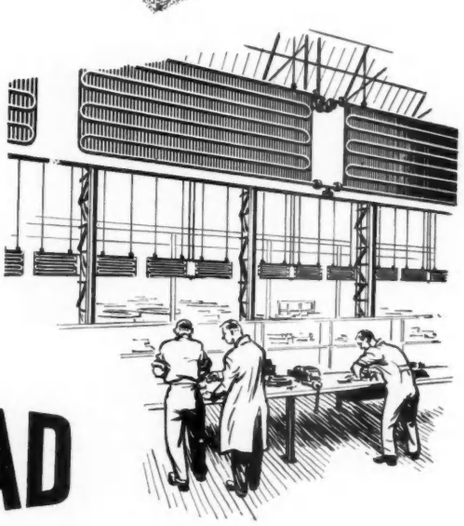

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ENGINEERING

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CHOICE

In America, at the beginning of the century, the steadily advancing frontier effectively reached the western seaboard. Inevitably, according to some observers, followed the stock-market crash of 1929. Because there no longer lay to the west a vast wild territory to which the young ambitious man could be sent, and which, no matter how inefficiently exploited, could yield tremendous dividends —because the apparently limitless *lebensraum* no longer existed—a complete re-orientation of the nation's economy became necessary. New Deal measures were often harsh; no longer could it be said "that government is best which governs least"; but out of the horror and pain of re-birth emerged a new, perhaps even stronger United States. To-day the entire world is faced with the same problem. There is only one last, bitterly inhospitable, continent left to conquer. The continents already conquered refuse—with some reason —to be exploited. We are left with a choice, a choice between two clear alternatives.

When Mr. Ben Lyon, the radio comedian, cries with mock desperation: "Stop the world, I want to get off!" he is voicing a feeling which, at least subconsciously, is common to many of us. The vogue for space fiction is not merely a passing fashion but a satisfaction for escapist appetites. Yet it is not only the longing for light and air and wide-open spaces felt by the city dweller that creates the need and leads to this recourse, but a deep-rooted barely conscious claustrophobia, a fear that as long as nuclear weapons exist, given time, just like the monkeys tapping out the works of Shakespeare, some fool eventually, inevitably, will drop a bomb on us. Even without that, we are suspicious that long-lived fission products will gather in our bodies and poison or disfigure us. This may be an unfounded fear, but it is not, as we are sometimes led to believe, the housewife (who is too busy), or the adolescent communist (who is too preoccupied), or the journalist (who forgets what he's written as soon as he's written it), who display the most anxiety, but the physicist and physiologist—and their uncertainty is significant. There seems nowhere left to go, at least on this planet.

Perhaps, therefore, it is time to take more seriously the prospect of space travel, to regard the books of H. G. Wells as primers, and to take into our councils those supposedly eccentric gentlemen of the Inter-Planetary Society. After all, an artificial satellite is to be launched during the forthcoming International Geophysical Year. Perhaps we are not yet ready to think in terms of journeying by "relativity space warp," but we should bear it in mind. The Massachusetts Institute of Technology already run a course on space travel.

More plausible, perhaps, is the suggestion made by Sir Raymond Priestley in his presidential address to the British Association last week that Antarctica be considered as a place for human settlement. Abundant atomic power, he believes, can make the Antarctic useful and comfortable, if not a paradise, but some worth-while economic objective must be discovered. Aerial surveys might reveal rich mineral deposits, which must surely exist in so large a continent. To exploit them, a power project no larger than the Kitimat scheme would, at least initially, be adequate, though finance and organisation on a national, perhaps international, scale would be essential to make certain of success. Competition for strategic bases is likely to lead to some polar development, since with the possible destruction of the Suez and Panama canals in time of war, shipping would be forced to take the Cape routes. Sir Raymond also proposed the use of the Antarctic as a cold store for the world's surplus food supplies. However, if the seventh continent is to be made fully habitable, some means must be found of overcoming the latent heat of ice; incidentally, the consequent rise in water level would cause the greatest slum clearance in the other six the world has ever known.

Thus the first of the available choices is to find somewhere new to live, whether in another world, or in the Antarctic. The second is simpler. Men can learn to live in a limited world as the Americans learned to live in a limited continent. One problem is that of growing population; either it must be restricted or food cultivation must be indefinitely increased. Dr. C. B. Goodhart, speaking before Section D of the B.A., however, opposes the Malthusian view that human populations will rise geometrically and so outstrip food supplies, and believes that biological selection against high fecundity may prove paradoxically a natural means of limiting population. Whether or not this is true, the short-sighted folly of trying to maintain the birth-rate in order to avoid an excess of older people is likely to end in catastrophe.

But whichever of the two courses we choose, whether it be expansion or consolidation, the means must be provided by technology. If we are to seek new fields then the engineer must find a way to make them habitable or design the craft to take us there. If we stay at home he must show us how to get more out of our resources. Probably our final choice will be a combination of the two.

Office of the Mayor
CITY OF NEW YORK
Proclamation
Whereas:

Plain Words

There is no truth in the rumour that a well-known American technical publisher is planning to launch a new periodical with the title " Automation Week." We are able to state that the rumour sprang from a misunderstanding of a Proclamation by the Mayor of the City of New York. A copy of the document which gave rise to all the confusion has arrived from New York and is reproduced above.

It shows that the period November 26 to 30 next has been designated Automation Week in that city. The Third International Automation Exposition is to be held at 500 Eighth Avenue, and the Mayor urges his " Fellow Citizens And The Visitors Who Will Then Be In Our Midst To Take Heed So That Maximum Advantages Will Accrue To Us All And That There Will Be Greater Security And Comfort In The World Of The Future ".

In England we would like to think that the proclamation did not end with the signing of the document; that the glad news was, in fact, proclaimed (does New York, like old York, boast a herald ?). It may be that in England we miss half the fun of life by reserving traditional forms for traditional ceremonies, and that we, like the Americans, could re-invigorate the nation by more readily grafting the old on to the new. Alas, in England mayors are sticklers for tradition unmodernised ! Those who are Lord Mayors were usually educated on the classics, and those who are just plain mayors are usually local trade union leaders.

BRITISH AIRCRAFT TO-DAY

1—CIVIL TRANSPORT

During the past week the annual display of the Society of British Aircraft Constructors at Farnborough has been in progress; it finishes on Sunday. In this series of articles we propose to describe some of the newer aircraft, engines and equipment to be seen there. We commence with the airliners.

Although the British commercial aircraft industry has not attained the supremacy in the world aircraft markets that seemed possible some five years ago, statistics given by the Society of British Aircraft Constructors on July 31 show that more than half the turbine-powered airliners for which orders have been placed throughout the world are British—451 out of a total of 880, and of these 342 are Viscounts.

VISCOUNT 802

The latest Viscount being demonstrated at Farnborough this year by Vickers-Armstrongs Limited, Weybridge, is the first of the 800 series and flew for the first time on July 27. For short-haul work, the 800 series represent a distinct advance in operational flexibility and economy in operation over the present very successful 700 series Viscounts, which show to better advantage on medium-stage distances.

The Viscount 802 (Fig. 1), flying at Farnborough, will shortly be delivered to British European Airways, the first of 24 of the type. The lengthened fuselage—9 ft. 3 in. longer than the Viscount 700 series—enhances its appearance and enables it to carry up to 70 passengers. Forward and rear baggage, or freight, compartments at cabin deck level have useful capacities of 175 cub. ft. and 90 cub. ft., respectively; also below the cabin floor is a hold giving a useful capacity of 225 cub. ft.; the doors to this hold give access for servicing various aircraft systems.

Movable bulkheads permit the forward freight hold and pantry space to be used alternatively for additional seating or toilet accommodation and, in B.E.A.'s aeroplanes, the use of folding lightweight passenger seats makes it possible to convert the cabin rapidly for use as a freighter. (These seats, incidentally, make possible a weight saving of 350 lb. per aircraft; they have been developed for B.E.A. by Short Brothers and Harland, Limited, and are on view in the static exhibition hall.) The aircraft seat rails, which provide for rapidly adjusting the spacing of the seats, are also fitted with freight-lashing rings, and the cabin floor is stressed to withstand a loading of 100 lb. per sq. ft. A 5 ft. by 4 ft. freight door at the forward end of the aircraft facilitates on- and off-loading by fork-lift trucks. Passengers enter through a door at the aft end, portside and opposite the main passenger door is an emergency exit door.

The principal dimensions of the aircraft, which is structurally basically similar to earlier versions, are as follows:—length, 85 ft.; height, 26 ft. 9 in.; wing span, 94 ft.; gross wing area, 963 sq. ft. The total fuel capacity, in multi-cell bag-type tanks, is 1,944 Imperial gallons. Power is provided by four 1,780 e.h.p. Rolls-Royce Dart propeller-turbines driving Rotol propellers.

At the maximum take-off weight of 62,500 lb., the Viscount 802 will take off and clear a 50 ft. obstacle within 1,800 yards. It will land over a 50 ft. obstacle in less than 1,200 yards at the maximum landing weight of 57,000 lb. At a cruising speed of about 315 m.p.h., the maximum payload, about 12,650 lb., can be carried over a stage distance of 680 statute miles; and over the maximum practical stage distance of 1,500 miles, a payload of about 5,900 lb. can be carried.

The Viscount 802 is the forerunner of a progressively advancing series of short-haul air-liners as more powerful Rolls-Royce Dart variants become available, culminating in the 400 m.p.h. Viscount 840, which, powered by Dart R.Da.8 engines derated to 2,080 e.h.p., will become available in 1959.

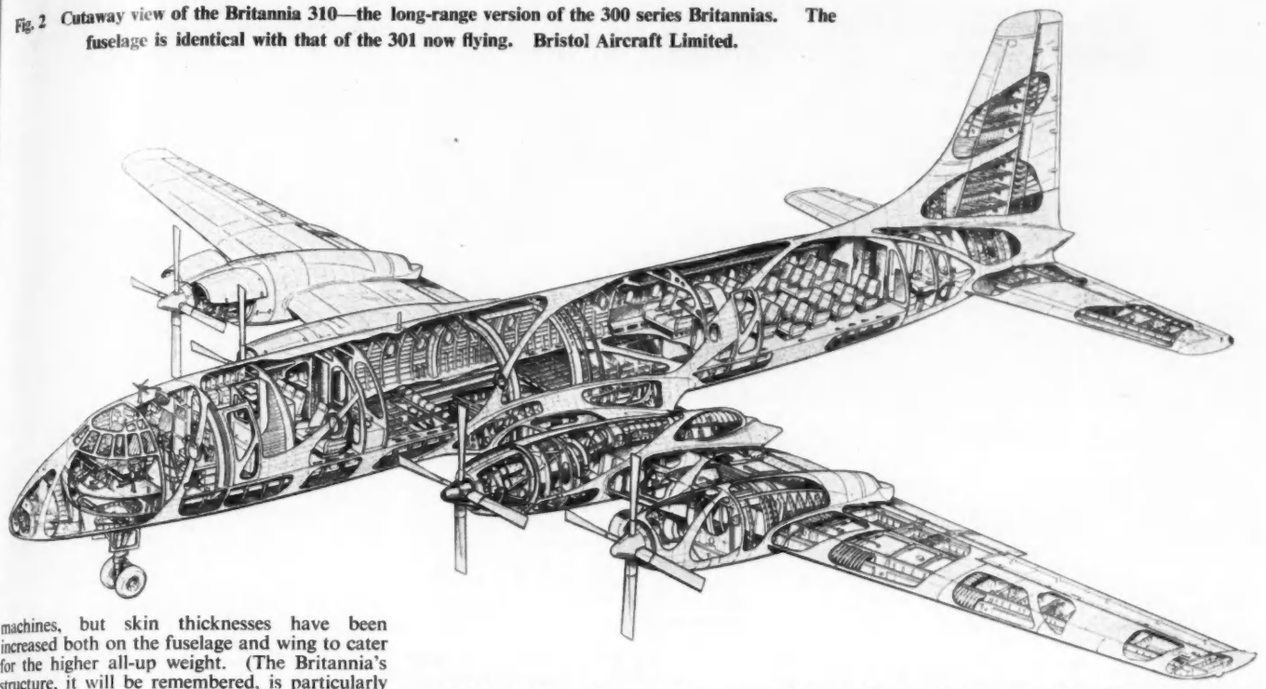
BRITANNIA 300 SERIES

Orders for the Britannia aircraft now stand at 55, and it seems possible that this number will be increased—and that a second British turbo-propeller airliner will invade the American market—as a result of Bristol Aircraft Limited's recent tour of the United States with a Britannia, which has attracted much favourable attention. The low noise level of this large aircraft is a characteristic not possessed by any other contemporary machine, and must have been a revelation to the American public.

Flying at Farnborough this year is the latest version, the Britannia 301 powered by four Bristol Proteus 755 propeller-turbines each developing 4,120 e.h.p. for take off. As Fig. 3 shows, the lengthening of the fuselage by 10 ft. 3 in. has added to the shapeliness of the Britannia as well as increasing the passenger capacity, in the tourist version planned by B.O.A.C., from 90 to 99 seats. In a high-density " coach " type layout, up to 132 passengers can be carried. The other principal differences between this aircraft and the earlier 100 series—production of which is now drawing to a close—are the provisions of three emergency exit doors at the rear fuselage, from which emergency chutes can be used for evacuation, and escape windows in the centre section over the wing. The cabin differential pressure has been stepped up to 8·3 lb. per sq. in., the air conditioning ducting layouts are modified, and the centrifugal recirculating fans in the air conditioning system have been replaced by quieter injector pumps. Basically the structure is similar to the earlier

Fig. 1 The Viscount 802 prototype airliner. Vickers-Armstrongs (Aircraft) Limited.

Fig. 2 Cutaway view of the Britannia 310—the long-range version of the 300 series Britannias. The fuselage is identical with that of the 301 now flying. Bristol Aircraft Limited.



machines, but skin thicknesses have been increased both on the fuselage and wing to cater for the higher all-up weight. (The Britannia's structure, it will be remembered, is particularly efficient and contributes only 23·5 per cent. of the total weight of the aircraft). The undercarriage, also, has been strengthened and the mechanism by which the lowering and retracting of the undercarriage units is used to open and close the undercarriage doors has been simplified. The manually-operated flying controls remain unchanged.

The cabin, 77 ft. long and 12 ft. in maximum width with a gangway height 6 ft. 8 in., is unobstructed throughout its length so that movable bulkheads can be fitted, as desired, and changed quickly to suit the operation. A standardised seat-rail system enables the seating to be rapidly changed in pitch and from two abreast to three abreast on either side of a gangway. Two large air-conditioned and pressurised underfloor freight holds, with capacities of 386 cub. ft. (forward hold) and 459 cub. ft. (aft. hold) are stressed to take a loading of 75 lb. per sq. ft.

The leading particulars of the Britannia 301 are as follows: span, 142 ft. 3 in.; length, 124 ft. 3 in.; height, 36 ft. 8 in.; wing area, 2,075 sq. ft.; aspect ratio, 9·76. The maximum all-up weight is 160,000 lb., and the landing weight 129,000 lb. The fuel capacity, carried in bag-type tanks in the wings, is 6,688 Imperial gallons.

The mean cruising speed at maximum continuous power is about 396 m.p.h.; for economical cruising a speed of about 346 m.p.h. is recommended. Under these conditions, the still-air range, when carrying the maximum payload of 30,000 lb., is over 3,000 miles; with full fuel tanks, a payload of over 12,170 lb. can be carried, and the maximum still air range is about 4,900 miles. The manufacturer's estimates of direct operating costs, based on the standard American method of cost-computation, indicates that, from maximum range at maximum payload down to a range as low as 1,000 miles, the Britannia operating costs remain sensibly even and of a very low order.

Early next year the long-range non-stop transatlantic version of the Britannia 300 series is expected to fly, and a cutaway view of this aircraft is shown in Fig. 2. So far as the fuselage is concerned, the two versions are identical, but the long-range Britannia 310 has additional fuel capacity in integral fuel tanks in the outer wings, which are therefore made rather stiffer, giving a total capacity of 8,486 Imperial gallons and all-up weight of 175,000 lb. On this aircraft the maximum payload will be 28,000 lb. which can be carried over a still-air range of about 4,400 miles. The full 93-passenger complement with baggage can fly non-stop from London to New York.

COMET

The de Havilland Comet airliner has, strictly speaking, no place in a review of the 1956 S.B.A.C. flying display. We propose to mention it here, however, because the break into the American market of the Comet 4 and 4A airliners is one of the three major triumphs of the British aircraft industry during the current year. It is interesting to speculate on the reasons which led Capital Airlines to select the British jet airliner in preference to American projects. The operational suitability of the Comet for Capital's routes across the American continent is in itself hardly a sufficient explanation, and it seems likely that other factors may have influenced Capital: their happy experiences with Rolls-Royce turbine engines (88,000 engine flying hours on the Dart without a single engine failure); the fact that the Comet alone of the turbojet airliners has a background of commercial experience, and is known to be an excellent aircraft from the maintenance standpoint, as well as a joy to travel in; and the thorough "de-bugging" that the Comet has gone through as a result of the Royal Aircraft Establishment's very searching technical investigations after the Comet disasters.

The Comet 4A, which will constitute the larger part of Capital's Comet fleet, offers air-line operators a high-speed jet aircraft capable of operating over short and medium-stage routes at competitive costs. Compared with the Comet 4, the fuselage has been lengthened by 40 in. This enables more than 70 people to be carried in a first-class four-abreast configuration and up to 92 people in a tourist-class five-abreast layout. The wing span has been reduced from 115 ft. to 108 ft. This, coupled with some structural reinforcement of the rear fuselage and tail, enables a higher cruising speed to be obtained at lower altitudes.

By cruising at a lower altitude the true air speed is increased relative to the limiting Mach number. This increase in speed goes far to compensate for the increased fuel consumption due to the reduced cruising altitude. A higher rate of climb and descent will be adopted, resulting in the maximum possible distance for high-speed level cruise.

This operating procedure enables the Comet 4A to cruise between 520 m.p.h. and 545 m.p.h., according to the ambient temperature, when flying at 23,500 ft. Because of the resulting improvement in block time the Comet 4A achieves good operating economy on stage lengths of 500 statute miles or less. At the upper end of the scale the high-speed cruise procedure shows advantages up to some 2,000 statute miles.

The maximum payload for the 70 seat version is 19,070 lb. and that for the 92 seat arrangement is 22,690 lb. With these payloads the Comet 4A, using the high-speed procedure, is capable of maximum stage lengths, in still air with full fuel reserves, of 2,040 statute miles and 1,880 statute miles, respectively. The all-up weight of the two versions of the Comet is the same at 152,000 lb. and the take-off and landing performance of the 4A suffers little by comparison with the Comet 4 which, as is well known, is exceptionally good.

The Comet 3 is now about to be fitted with Rolls-Royce Avon RA.29 engines of 10,500lb. take-off thrust, and will begin certification flight testing later this year specifically for the Comet 4 and 4A. It will incorporate all significant features of the new aircraft, including the shorter wing span of the Comet 4A. Detachable wing tips will enable quick conversion from the Comet 4A to the 4 shape for test-flight evaluation. A fully representative prototype, therefore, will become available for certification flying about 18 months before the first deliveries of Comet 4's and some 30 months before deliveries of Comet 4A's.

THE PRESIDENT

The President airliner demonstrated for the first time by Hunting Percival Aircraft, Limited, Luton Airport, is a civil development of the Pembroke military communications aircraft which is itself a strengthened-up version of the versatile Prince aircraft. It is powered by two Alvis Leonides engines each developing 550 h.p. for take-off.

The President can be fitted with up to 11 forward or rearward-facing seats (one being a two-seat unit) and for freighting duties it offers the same spacious cabin and low-loading facilities as the Pembroke. It is well suited for photographic air survey, provision being made for fitting forward- and side-facing oblique cameras and a vertical camera. The use of an automatic pilot renders the President a remarkably steady photographic platform at heights up to 20,000 ft.

Fig. 3 The Britannia 301 prototype airliner. Bristol Aircraft Limited.

In its executive form, in which it is being demonstrated at Farnborough, the President is laid out as an attractive six-passenger personal air-liner for private and business use.

The total usable fuel capacity of the President gives a still air range of 1,030 statute miles at an economical crusing speed of 150 m.p.h. This distance can be increased to 1,500 statute miles by fitting underwing slipper tanks. Over shorter distances the President can maintain a speed of up to 220 m.p.h. at maximum rich mixture settings and has a service ceiling of 22,000 ft.

HERALD AND TWIN PIONEER

Among the airliners that have been seen at previous Farnborough displays, the Herald "D.C.3 replacement" 44 passenger air-liner, constructed by Handley Page, Limited, Reading, has been ordered by Queensland Airlines, Australian National Airways, Lloyd Aereo Columbiano and Air Kruise (Kent), Limited. The first prototype has carried out performance, take-off and landing tests for certification, and the second prototype, due to fly this summer, will be used for proving the cabin pressure system, de-icing systems and for tropical trials, after which it will be put into air-line service for intensive development under commercial operating conditions. Structural tests are in progress on a complete fuselage at Radlett, and a second fuselage is undergoing pressure tests at Woodley, Reading.

The Twin Pioneer 16 passenger airliner, designed and constructed by Scottish Aviation, Limited, Prestwick, for operation from restricted spaces with no runway facilities, expects shortly to acquire its certificate of airworthiness, and, with this accomplished, a number of potential purchasers from various parts of the world who have shown interest in the machine are likely to place definite orders. Scottish Aviation are, therefore, laying down a production line for a run of 200 aircraft. The possibilities of developing this type of aircraft, rather than the complicated helicopter, for inter-city operation deserve serious consideration.

Letters to the Editor

ELECTROMAGNETIC PUMPS FOR LIQUID METALS

SIR, Electromagnetic pumps developed for pumping liquid metals give an efficiency according to one firm who make them (the British Thomson-Houston Company) varying from 35 to 42 per cent.

If the work done by the current in producing a given head of pressure at a given delivery volume is equated to the direct-current electrical output which should result from propelling the fluid under corresponding velocity and volume past the magnetic field, then in the case of mercury, the ohmic resistance loss in the fluid works out at about 14 per cent. in a typical case.

Allowing a hydraulic frictional loss of 10 per cent. the pump ought to have a 76 per cent. efficiency. Why is the actual efficiency only about half of this? An ordinary electric motor (with "solid" conductors) yields an efficiency of 89 to 90 per cent. A good centrifugal pump would give 75 per cent. efficiency at least.

Why then does the liquid metal conductor operate so inefficiently? The loss, as stated above, can hardly be ohmic resistance alone but some other factor seems to be involved. Is it turbulence or is it due to the fact that the liquid molecules being "free" and not "bound" as those of a solid, absorb current uselessly in having their *individual* random motions increased instead of a *mass* increase, the ratios being perhaps 50 : 50. The would represent a heating effect superimposed on the ordinary ohmic resistance, so accounting for the low efficiency. It is unfortunate the latter is so low, as the electromagnetic pumps furnish a very simple and straightforward method of producing velocity or pressure in liquid metals such as are now being tried out as heat transporters in atomic power reactors taking the heat outside to steam generators.

I do not think we can rule out the probability that if the motor principle as applied to liquid metal flows is sub-normally efficient the converse might occur when it is used to generate current instead of absorbing it to produce pumping effects.

For it is the velocity of conductors traversing the magnetic field that primarily determines the voltage and current produced, and with a fluid conductor there are at any given instant a certain percentage of molecules (in this case positive metallic ions) possessed of forward velocities greater than the average *mass* velocity, and a similar percentage of others correspondingly slowed down by ballistic interchange of momenta to produce these higher velocities, the result being that the faster moving molecules possessing in consequence as their momentum one component due to mass-flow and an equal component due to internal molecular velocity will generate a total current of maybe 100 per cent. in excess of the mass energy absorbed as resistance overcome.

With the motor principle, on the other hand, when the liquid is got moving, molecules with near-zeroed velocities, a certain percentage of which must exist at any given instant, are urged along by the traversing current to near-average *mass* speed, producing an overall heating effect resulting in the low efficiency realised, lower than if ohmic resistance alone had to be reckoned with. The latter loss is owing chiefly and merely to the relative difficulty electrons have in threading their way through the molecular crystal lattice, as it is termed, with different conducting substances.

Yours faithfully,
H. J. NORTHFIELD.

332 Bramford-road,
Ipswich,
Suffolk.
August 28, 1956.

★ ★ ★

THICK WALLED CYLINDERS UNDER INTERNAL PRESSURE

SIR, We were interested to note that Helmut Leinss (ENGINEERING, vol. 180, page 132, 1955) was able to represent the experimental results of Crossland and Bones (ENGINEERING, vol. 179, pages 80 and 114, 1955) concerning the strength of thick-walled cylinders, by the empirical relation,

$$\frac{(K-1)}{P}\sigma = \alpha = \alpha_1 + \beta(K-1)$$

where K is the ratio of outer to inner diameters of a cylinder, σ is the ultimate tensile stress of the mild steel, P is the experimental bursting pressure, and α_1 and β are independent of K.

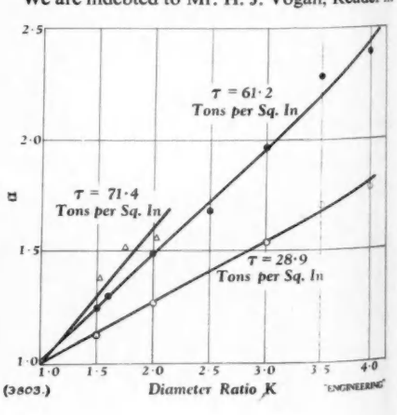
Leinss pointed out that, since $(K-1)\sigma$ is the bursting pressure of a thin cylinder α_1 should be unity, and this was found to be true for the results of Crossland and Bones.

We felt it worthwhile to investigate the question, raised by Leinss, of whether such a relation is valid for other materials. Accordingly we have analysed some published results to test their conformity with the above relation, putting in σ, the ultimate stress, or τ, the yield stress, appropriate to the experimental pressures of bursting or yielding of cylinders. The results of Cook and Robertson (ENGINEERING, vol. 72, page 786, 1911) and Cook (*Phil. Trans. Roy. Soc.*, vol. 230A, page 103, 1932) and *Proc. I.Mech.E.*, vol. 126, page 407, 1934) for mild steel, those of Cook and Robertson (*loc. cit.*) for cast iron, and those of MacRae (*Overstrain in Metals*, H.M.S.O., 1930) for nickel steel are satisfied with only small random errors to equations of the above form. In most cases, however, α_1 is less than unity.

There is some indication that β, the slope of the α,K-line varies smoothly with τ for a particular material. To investigate this further we have measured the yield pressures, in the range 2,000 to 12,000 atmospheres, of some cylinders of a Ni-Cr-Mo steel, heat-treated to three different tensile strengths. The values of K range from 1·5 to 4·0 for two of the specimens and from 1·5 to 2·0 for the specimen of highest tensile strength. The results are shown in the diagram where it will be seen that β increases as τ increases. It is interesting to note that, if a simple relationship could be established between β and τ for a given material, this relationship, together with the Leinss formula, would permit the prediction of yield pressures of cylinders of given dimensions and tensile strengths without further tests.

It is intended to publish later full details of our experimental method and of the results.

We are indebted to Mr. H. J. Vogan, Reader in



Civil Engineering at the University of Sydney, for carrying out the tensile tests.

Yours faithfully,

H. G. DAVID.
S. D. HAMANN.

Division of Industrial Chemistry,
C.S.I.R.O.,
High Pressure Laboratory,
University of Sydney, Australia.

★ ★ ★

THE RECIPROCAL THEOREM

SIR, Further to my article "The Concepts of Real and Virtual Work," which appeared on page 139 of your issue of July 29, 1955, I would like to call attention to a proof of the Reciprocal Theorem, for linear structures, using the Principle of Virtual Work.

Betti's form of the Reciprocal Theorem is as follows:—

$$\Sigma F y' = \Sigma F' y$$

where F denotes an external force applied to a structure and y denotes deflection of the structure. The system of external forces F_1, F_2, etc., acting alone, produces deflections y_1, y_2, etc., in the directions of F_1', F_2', etc., respectively, while the system of external forces F_1', F_2' etc., acting alone, produces deflections y_1', y_2' etc., in the directions of F_1, F_2, etc., respectively. The points of application denoted by 1, 2, etc. are common to the two systems of external forces and the summations include the whole of the structure under consideration. It should be noted that the validity of this theorem depends upon the structure as a whole obeying Hooke's law, i.e., each individual member must obey Hooke's law and the deflections must be sufficiently small that non-linearity due to distortion (change of geometry) of the structure does not arise.

If the structure is pin-joined, the forces in the members due to the system of external forces F can be denoted by T, and the corresponding extensions or contractions by $e = \frac{Tl}{AE}$, where l is the length, A is the cross-sectional area and E is the Young's modulus of a member. Again, for the system of external forces F′, the forces in the members will be denoted by T′ and the corresponding extensions or contractions by $e' = \frac{T'l}{AE}$.

Now, the combined systems of external and internal forces F and T constitute a system in equilibrium, while the combined systems of external and internal forces F′ and T′ constitute another system in equilibrium. Also, the combined systems of external and internal deflections y and e constitute a system of displacements which is compatible with the geometry of the structure, and the combined systems of external and internal deflections y' and e' constitute another such system of compatible displacements. Thus, by the Principle of Virtual Work we can write:—

$$\Sigma F y' = \Sigma T e'$$

and

$$\Sigma F' y = \Sigma T' e$$

Putting $e = \frac{Tl}{AE}$ and $e' = \frac{T'l}{AE}$ and substituting in the above equations, it is found that:—

$$\Sigma F y' = \Sigma T T' \frac{l}{AE}$$

and

$$\Sigma F' y = \Sigma T' T \frac{l}{AE}$$

that is:—

$$\Sigma F y' = \Sigma F' y$$

which is the well-known form of the Reciprocal Theorem known as Betti's Theorem. It is, of course, possible to include terms for moments and rotations, but these were omitted above to avoid unnecessary complication.

Yours faithfully,

T. M. CHARLTON.

Engineering Laboratory,
University of Cambridge.
August 16, 1956.

Weekly Survey

Cover Picture: *This week our illustration shows the edges of a specially woven heat-resisting wire-mesh belt being finished. The belt combines high strength at elevated temperatures with low weight and heat capacity. The mesh is formed into an endless conveyor for a wash-belt conveyor furnace for bright copper brazing, bright annealing and normalising, and other heat-treatment operations.*

(An error occurred in the note on the cover picture of our issue of August 31. In the ninth line the words "from the quartz fibre" should have been omitted).

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Plastics go to Sea

Progress towards the adoption of polyester resins reinforced with glass-fibre in boat building has so far been cautious. This form of construction has come to be accepted for small dinghies, but the innate, and well-founded, conservatism of sailors the world over has acted as a brake on the rapid adoption of new materials.

It is therefore particularly significant that interest in this form of construction is now being shown by fishermen. A strong delegation representing the Icelandic fishing industries have visited England this week to study the techniques developed by Halmatic Limited, of Portsmouth, for the production of fishing boat hulls up to 73 ft. in length and 15 ft. beam. This mission, which includes the chairman of the Committee of Icelandic Fisheries and the secretary of the Union of Icelandic Fishing Vessel Owners, has in mind the possible production of glass-fibre hulls in Iceland under licence.

If this visit should bear fruit, it will represent a major step forward in the use of glass-fibre reinforced plastics. Following a start during the war on aircraft parts such as radomes, they have been used increasingly for motor-vehicle body components such as wings, bonnets and doors, and for complete bodies. The advantages offered are perhaps more apparent in boat construction than elsewhere. While first costs have until recently tended to be high, maintenance costs are sharply reduced; glass-fibre construction offers the owner a hull virtually immune from the depredations of corrosion and marine borers, while initial cost is now said to compare favourably with that of construction in teak and steel.

The size of moulding contemplated in this country has steadily increased. Eighteen months ago, the Admiralty were carrying out trials on a 20 ft. motor dory, and regarded both the technique of construction and the basic materials as being in an early stage of development. At that time, the high cost of unworked materials and the alleged uncertain quality of some constructional efforts were considered as pointing to the need for more intensive research. However, during the last 18 months a number of hulls have been constructed of up to 54 ft. length, which are reported to be giving satisfactory service.

The material has much to offer in this field, and widespread acceptance could lead to an appreciable reduction of first costs. The outcome of the Icelandic visit will therefore be awaited with interest. Approval of glass-fibre construction by such a body could have a strong effect on opinions elsewhere which are, at least in part, composed of prejudice.

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Plastics Grounded

If plastic ships are to be produced on any appreciable scale in the near future, this development may improve the position in the plastics industry, for output is currently undergoing a slight recession. After a rise in output of some 53 per cent. in 1955 it was confidently anticipated that a further increase of at least 20 per cent. could be expected in 1956. The effects of the credit squeeze on demand from the consumer goods industries is making this forecast somewhat optimistic however, since current output is showing little improvement, if any, on 1955 levels. The chief setbacks have been in polyvinylchloride and polystyrene. The new polystyrene plant of Monsanto Chemicals, Limited, is said to be running at only two-thirds of capacity, while output of p.v.c. has been affected, not only by declining demand, but also by severe price-cutting competition from Continental and Canadian producers.

Polythene output is, however, still rising. Further evidence of the industry's faith in the future of this material was given by Monsanto Chemicals last week, when they announced the first stage of a long-term development programme in petrochemicals, involving an expenditure of some £8½ million on a plant for the manufacture of 10,000 tons of polyethylene a year. The plant is to be erected on a 100 acre site adjacent to the Fawley refinery of the Esso Petroleum Company, Limited, from which it will draw the essential raw materials. Production is scheduled to start in 1958. This plan, together with others announced by Imperial Chemical Industries Limited and the Union Carbide Company, will bring total planned expenditure on polyethylene development announced this year to a total of nearly £29 million. Meanwhile the Shell subsidiary, Petrochemicals Limited, continues to develop its project for the production of polyethylene by the new Ziegler process. Here is certainly no counsel of despair in the plastics industry.

The second stage of the Monsanto plan at Fawley envisages the production of copolymers of acrylonitrile, butadiene and other monomers. This will increase the supply of raw materials for the plastics industry and also for the growing synthetic rubber industry, and the paint and paper industries. Acrylonitrile itself, which will be produced during the third stage of Monsanto's expansion, is an essential raw material for many types of synthetic fibres. Its production in this country reflects the company's policy of maintaining and developing indigenous sources of basic raw materials, and it is likely that much of the acrylonitrile produced at Fawley will go to the projected plant for the production of "Acrilan" fibre in Northern Ireland by the Chemstrand Corporation, which is jointly owned by Monsanto and the Viscose Corporation of America.

It is interesting to note how four relatively new industries have pursued an expanding and interwoven course since the war. Three of them —plastics, petrochemicals and synthetic fibres— owe much to the far-sighted policy of developing the fourth, namely petroleum refining, in this country. If refinery expansion in this country keeps pace with the anticipated increase in demand for oil, a growing supply of raw materials for a variety of industries will be assured.

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To Damascus

In view of the growing importance of the Middle East market as a whole it is welcome news that at the third Damascus International Fair, which opened on September 1, British participation is on a larger scale than that of any other country. The United Kingdom section, which is appearing for the first time, covers the products or services of more than 100 British firms and has been organised by the Federation of British Industries through its subsidiary company, British Overseas Fairs Limited. Though by no means confined to the engineering industries, the latter are strongly represented, particularly manufacturers of motor vehicles and accessories, radio and television, agricultural equipment, Diesel engines, pumps, electrical machinery and office machinery.

In 1955 total United Kingdom exports to Middle East countries amounted to £134·3 million—an increase of about 30 per cent. on 1954 though there was a decline in the figure for that year compared with the £112·2 million of 1953. The most important individual markets in 1955 were Egypt, which took exports valued at £28·7 million, Iraq £26·5 million, the Persian

Gulf States (including Kuwait) £20·6 million and Iran £17·7 million. The United Kingdom is the principal source of imports for Iraq, accounting for 28·9 per cent. of total imports, and also for Iran (19·8 per cent.), Syria (14·4 per cent.) and the Persian Gulf States (42·5 per cent.). In the case of Israel the principal supplier in 1955 was the United States (29·4 per cent.) followed by Germany (17·8 per cent.) and the United Kingdom (10·3 per cent.), while in the case of Saudi Arabia the United States (45·5 per cent.) was the principal source of imports, followed by the United Kingdom (17·1 per cent.). These figures show the extent to which trade follows political influence in the various countries and provide yet a further reason why it is so important that this country should find a solution to the Suez dispute which will not impair British prestige in the Arab countries.

In spite of the very rapid increase in Middle East oil output in recent years, the area accounted for only 20·9 per cent. of total world production. Middle East oil reserves, however, account for 66·4 per cent. of total world resources and unless political difficulties prove insuperable, production must continue to expand until these two figures are more nearly in line. The growing oil revenues should result in a rapid expansion of imports into the area and it is to be hoped that the British exhibits at the Damascus Fair will help to consolidate the position of the United Kingdom as one of the leading sources of imports.

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The Percival One-Man Band

Elsewhere in this issue will be found a description of an agricultural aeroplane which, in these post-war times, is unique in that it has been designed and test-flown by the chairman and managing director of the company that manufactures it—Edgar Percival Aircraft Limited, of Stapleford Aerodrome, Essex.

Before the second World War Mr. Edgar Percival was designing and constructing a famous line of aircraft, as Percival Aircraft Limited, at Luton. Among the more notable achievements of Percival aircraft are Charles Kingsford-Smith's England-Australia flight in 1933, Amy Mollison's England-South Africa flights in 1936, and Jean Batten's England-New Zealand flight in the same year—all international records. In 1946, however, Percival Aircraft Limited was sold to the Hunting Group, and is now known as Hunting-Percival. Mr. Percival returned to the aircraft manufacturing field in 1953, when he conceived the idea of an agricultural aircraft. After an investigation of the requirements of Australia and New Zealand, where the agricultural applications of aircraft are more highly developed than anywhere else in the world, he set up the present company in 1954, as a private venture to design and construct the E.P.9—the ninth Percival aircraft to go into production.

Although the export potentialities of the E.P.9 are considerable—and will cost the taxpayer nothing—it has not been possible to show this aircraft in " the industry's shop window " at Farnborough. The Society of British Aircraft Constructors will not at present accept Edgar Percival Aircraft Limited as members because their turnover has not yet reached the prescribed value. Even if it had, the E.P.9 could still not have been displayed before the overseas guests at Farnborough, because it has an American engine and airscrew. Why American? Because, to provide the excellent view required for landing on restricted fields and for operating at low altitude, a flat horizontally-opposed engine was essential; and such an engine is not available on the British market.

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Overseas Civil Engineering Contracts

In spite of the loss of the main civil engineering contract for the Kariba project in Rhodesia, there has been a marked rise over the past eighteen months in the value of new work obtained overseas by British civil engineering contractors. Estimates issued for the first time by the Advisory Council on Overseas Construction show that new orders received for the year ending March 31, 1956, amounted to £105 million, an increase of 40 per cent. on the figure of £75 million for the previous year. The estimated value of work outstanding at March 31 rose from £70 million in 1955 to £80 million in 1956.

These figures relate to work carried out by British contractors operating from this country or by associated and subsidiary companies in which the predominant interest is British. They cover all types of building and civil engineering work. For comparison, the value of new work, other than housing, carried out by building and civil engineering contractors in the United Kingdom in 1955 totalled £621 million. The value of work done at home rose in the first quarter of 1956 to £167 million, compared with £131 million in the first quarter of 1955, and there was a further rise in the second quarter of the year. Some decline in activity is, however, expected for the remainder of the year and a further expansion of work overseas would provide a welcome offset.

British civil engineering contractors have been particularly successful in Canada, the Middle East and Africa. Prospects for new contracts should be particularly good in the Middle East in view of the rapidly expanding oil revenues which already amount to nearly £400 million per annum. While there is strong competition in the area from both France and Germany, British contractors are supervising a £30 million road programme in Persia and have important contracts in Iraq including the Baquba railway bridge, the Jalaula Derbendi Kahn road scheme and the Greater Mussaib project. The Iraq Development Board plans to spend a further £300 million between 1955 and 1960. The second Indian Five Year Plan will also involve important civil engineering contracts.

The controversy following the allocation of the Kariba contracts showed that some British contractors are looking for special preferential treatment. This is not likely to be forthcoming, but there can be little doubt that the next few years will see a further expansion in civil engineering work overseas and, provided British contractors are able to compete for this on level terms, they should have little difficulty in offsetting any decline in work at home by increased overseas contracts.

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Heavy Engineering in India

The visit next month of a United Kingdom heavy engineering mission to India under the chairmanship of Sir Eric Coates is likely to have an important influence on the extent to which the British engineering industry will benefit from India's second Five Year Plan. The mission is being formed under the joint auspices of the Federation of British Industries and the Colombo Plan, and its object will be " to advise on the further extension of heavy machinery manufacturing capacity during the period of the Five Year Plan." An advance party flew to New Delhi at the end of August to undertake preliminary work of an exploratory nature.

It is clear that India will need all the help she can get if the plan is to be successfully carried out. The United Kingdom is already giving advice on the establishment of jet aero-engine and air-frame manufacturing plants, while an American team is advising on the establishment of an aluminium plant. In July, a Russian team went to India to investigate the possibility of establishing a heavy machinery factory.

Although the United Kingdom heavy industry mission's work will be purely advisory, the extent to which it is likely to influence the placing of orders has already been shown in connection with the expansion of the Indian iron and steel industry. The German Krupp-Demag group were appointed consultants for the first of the proposed Government-owned steel plants at Rourkela, and the main contracts for erection of the works have been secured by Krupp. It was announced last week that the contract for the steel mill at Rourkela, valued at £10 million excluding scrap recovery installations and assembly costs, had been awarded to Krupp, and it was expected that contracts for the rolling mill valued at £35 million, would be secured by a German consortium comprising Krupp, Demag, Schloemann, Fack and Siemag. The City of Rourkela itself, which is to house 100,000, will be built by Krupp, and a nitrogen plant based on hydrogen from the coke oven gas is also to be erected.

The Durgapur steelworks in West Bengal is, of course, to be built by a consortium of British engineering firms, and it may be hoped that further important contracts for the heavy engineering industry will result from the activities of the mission.

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Renting Motor Cars

An all-out bid is being made to enable the small business to have its car—or truck—without putting down the full 50 per cent. of the price of the vehicle required by hire purchase regulations. There is nothing fundamentally new about car rentals, but the schemes announced last week by the Standard Motor Company, Victor Britain (a London car hire concern) and Bond Minicars are likely to lead to a vast increase in this type of business. The Standard scheme—in association with Industrial Rentals—will be known as " Stanhire." Most schemes involve an initial payment of 15 per cent. of the retail price, 57 per cent. in the first year (to include the initial payment), 42 per cent. in the second year, and the rental declines in the subsequent six years. The payment of rental includes all insurance and maintenance costs, excluding accident repairs of less than £10. The contract can be terminated at one month's notice after the first year, and the rental company refunds the difference if the selling price is in excess of the percentage due that year. The schemes are available only for firms or business men who are able to justify the use of a car for business purposes. The rental payments are therefore a claim against income tax, as a business expense.

The Standard Motor Company consider that their scheme will attract " a lot of medium and small size firms and professional people who otherwise would not be able to afford a new vehicle," and therefore substantially increase car sales. Industrial Rentals' charges appear to be about 12 per cent. compared with about 8 per cent. charged for hire purchase. This does not seem unduly high for the convenience of having a car maintained in first-class condition. The demand may be heavy; if so, other manufacturers will doubtless produce schemes of their own. The Government's views have not yet been made known. There is a great deal to be said for making cars readily available to those who need them for their work, but any abuse of the scheme, or a major increase in car sales on the home market, would be likely to produce an adverse reaction from the Government.

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German Aircraft Again

One of the first fruits of the vast German re-armament programme has been to re-start the country's aircraft industry. Six months ago Dornier received orders for 469 liaison aircraft. Now a further 671 military transport and training aircraft have been ordered from other companies. The German firms will be concerned with the manufacturing of the airframes only; although more of the equipment will be made in Germany, the majority of the engines required will be imported. The German Government have granted credits of 35 million marks for tooling-up purposes, through the Bank for Reconstruction. Thus, only 11 years after the defeat of Germany, the Reich is once

more in a position to make military aircraft; it is a small step from airframe to complete units, and from jet trainers to jet fighters. It is a measure of the political bankruptcy of the post-war world that such a development should have taken place so soon.

A striking feature of the new programme is that nearly all aircraft and most of the aero-engines are to come from French, Italian or American designs. The only British design adopted is that of the Bristol Hercules piston engine as the power unit of the Noratlas transport. This engine, however, is no longer built by Bristol, but by the French Société Nationale d'Etude et de Construction de Moteurs d'Aviation, under licence. The Noratlas order, involving 117 transport aircraft, estimated to cost £330,000 each, is the most important. The airframe design is that of another French company, the S.N.C.A. du Nord, to be made under licence co-jointly by the Siebel company and the Weserflug and Hamburger Fahrzeug concerns. The famous Messerschmitt and Heinkel companies will join to make 360 French Fouga Magister jet trainers, the engines being imported from France (the Turboméca Marboré turbo-jet). Focke-Wulf of Bremen will build 194 Piaggio training aircraft. Both the Piaggio and the Dornier D.O.27 will be powered by an American Lycoming Type 435 piston engine, made under licence by the Bayerische Motoren Works.

Ten years is a long time for an industry as subject to rapid technolgiocal changes as is the aircraft industry to be idle. Some time will be required to narrow the gap between the German industry and its competitors. But it is likely that design teams have been active ever since the end of the war, and the period of building under foreign licences may prove to be surprisingly short. Already there are reports that the German aircraft industry is to export American aircraft assembled locally under the terms of the mutual aid agreement. They include 558 F.84 aircraft and 26 H.21 helicopters. The Dornier 27 will also be sold as a passenger aircraft. The German Aircraft Manufacturers Association look upon military contracts as a means to finance the industry's new start and for providing export openings.

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B.A. In The Steel City

Sheffield was the obvious choice this year for the annual meeting of the British Association. It is just a hundred years since Bessemer's famous steel process discovery. The fact that invention is still alive in the steel industry was shown by a paper from Sir Charles Goodeve. But engineering to-day is a vastly broader subject than it was in Bessemer's time—it calls in aid such diverse branches of learning as psychology, physiology, meteorology, biology, and, of course, the older sciences like physics. Hence the following notes on papers other than those from the Engineering section. Three of the engineering papers are published elsewhere in this issue.

* * *

Bessemer Converted

When Sir Charles Goodeve, delivering his presidential address to the Chemistry Section of the B.A., revealed that experiments on a new technique for reducing iron ore were in progress, he emphasised that the methods of chemical engineering had in the past received too limited an application. With the introduction of the "Cyclosteel" process, however, they had entered the world of steelmaking. It is worth noting also that nuclear-reactor engineers may follow chemical engineers in transporting solids as fluidised powders.

The essence of the Cyclosteel system will be its ability to deal with finely divided ores, which, at present, unless some form of pelletising is adopted, would tend to choke a blast furnace. It is, in Sir Charles's words, "an inversion of the Bessemer process," in which air bubbles are dispersed in liquid metal, for with Cyclosteel small droplets of liquid ore are distributed in a high-temperature reducing gas. It is reasonable to suppose that this development would give an even higher rate of reaction than Bessemer's method. Droplets would probably be less than 0·001 in. in diameter and the temperature of the gas would have to be in excess of 1,600 deg. C.; this presents a severe problem.

Paradoxically, the availability of tonnage oxygen has made possible the preparation of the required reducing gas in sufficient quantities, for injected into the furnace chamber with pulverised coal (or atomised oil or perhaps towns' gas), oxygen contributes to the formation of carbon monoxide, which serves to reduce the ore. This occurs in the first part of the process, in which the powdered ore is suspended in a flame where it is converted to liquid droplets and then reduced. Additions of lime and close control of the oxygen supply to a low potential ensures that silicon, phosphorus and carbon are removed from the metal so that the final product will be not pig iron but steel. Finally, the liquid metal is carried to the walls of the chamber by a whirl or cyclone effect and allowed to separate from the slag by gravity and surface tension in a settling chamber. Some preparation of the ore would be necessary, probably by pre-heating it in a fluidised bed to a temperature just below the point at which it becomes sticky, and then injecting it into the hot reducing gas.

A small pilot plant, of approximately ½ ton per hour capacity, has been built at the Middlesbrough laboratories of the British Iron and Steel Research Association—of which Sir Charles is Director—and initial trials, he believes, have given reason for optimism; perhaps in ten years Cyclosteel will be in general use. The process is not expected to replace the blast furnace, which is extremely efficient, but may be complementary to it. In fact the thermal efficiency of the Cyclosteel system may render it a doubtful competitor economically with the reduction of sintered and pelletised ores in a blast furnace; heat losses from ore to metal are very low with this method.

Some opposition to the new process has been expressed by Dr. J. H. Chesters, assistant research director of the United Steel Companies, who is reported as stating that no known furnace lining could withstand the temperatures at which it would be necessary to operate. Inasmuch as the refractory walls of the pilot plant have recently collapsed, this would seem to be true. A partial answer to the objection has been given by Sir Charles Goodeve, who has suggested that the metal itself, solidified on the furnace walls, would be used to provide thermal insulation, as has been tried in the case of titanium. Nevertheless, Sir Charles admits that there are many problems yet to solve.

* * *

Applied Evolution

The natural process of evolution by which living things are modified to fit them for life within their environment is believed by Dr. G. E. P. Box of I.C.I. to have an application to industry. Speaking before the Physics Section of the Association, he asserted that it could be imitated on the factory floor and used to find the best manufacturing conditions for a particular product.

Chemicals are normally produced by fixed process recipes in which such conditions as temperatures, times, concentrations, pressures and speeds of agitation are rigidly defined, so that the plant operator endeavours to reproduce the same conditions in every run of the plant. This might be called static operation. In the method of evolutionary operation, however, slight modifications would be made in the reaction conditions for each successive period of running. These "variants" would follow a carefully planned cycle which would be continuously repeated, and although the changes in the process conditions would be too small to modify the product of any particular run perceptibly, results could be averaged and evidence concerning the effects of the various changes built up. It would then be possible to determine how the process recipe and mode of operation could be modified in order to obtain a better product. This improvement would be embodied in the plant by making a modification in the direction indicated and a new cycle of variants would then be started about the revised base point.

Experience has shown that this procedure can be carried out with little additional expense and the operation thus slowly nudged into a form ideally suited to the particular plant concerned. To be most effective, the approach requires a team of technologists with complementary rather than common disciplines, meeting, say monthly, to provide the plant manager with ideas on new evolutionary directions. The system would then become virtually a mode of operation and should be so regarded.

Dr. Box considers that this technique could be applied in one form or another to a very large number of industrial processes, whether the plant be of the crudest kind or such as to include automatic controllers and recorders. On a sufficiently instrumented plant the procedure could be made completely automatic. Evolutionary operation presents a method of improving a process without removing the plant from commission for experimental runs and without the vast and perhaps unmanageable calculation that would otherwise be necessary. In effect the plant becomes its own analogue computer.

* * *

Fair Trial for Psychology

The assessment of personality, even the systematic judgment of a man's suitability for a given job or a child's ability to profit from higher education, is held in considerable suspicion by many people. They are supported by the humanists who, according to Professor J. Drever in his presidential address to the Psychology Section of the B.A., have been heard to say: "You can't have a science of behaviour." Their attitude may arise from a failure to accept the neutrality of science, to recognise that the results of science only become practical or ethical counters in the hands of those who are not scientists as such. The humanist may feel that the psychologist is in a position to think: "A sucker is born every minute, and our science may enable us to exploit him more efficiently." On the other hand, the psychologist's knowledge could equally well be used to "identify and educate" the sucker. What may be closer to the truth in the case of many people is that their rejection of psychology comes from a fear for their self-respect, a desire not to be seen through. This may certainly be a reasonable misgiving, but to abandon techniques of human assessment on that ground would surely be an error.

If, as Dr. C. M. Franks suggests in another British Association paper, we are sat in a slightly tilted chair in a darkened room and told to assess the verticality of a luminous rod in order to determine whether we are extraverts, introverts or neurotics, we shall probably accept the validity of the test only if its results are generous to our vanity. Similarly, but with greater justification, we shall subscribe to Miss M. D. Allan's view that man has "an innate capacity for perceptual organisation"—in other words, that perception is a function of experience—rather than the more familiar Gestalt doctrine that the forms of perception, the square, say, or the arrangement of the human face, are innate, only if her view proves useful to us in some way. In fact, she maintains that such a theory may help in the teaching of skills.

It is the potential, if not realised, usefulness of psychological methods that should make us ready to give them fair trial. Dr. D. H. Irvine and Mr. D. E. Broadbent provided some valuable contributions on the subject of vigilance in machine minding and the inspection of instrument dials or radar screens. Mr. Broadbent

stated, for example, that watching someone work can induce fatigue—a tendency most of us have noted in our colleagues. This observation does, however, lead to a useful conclusion. Men are very inefficient at watching passively for infrequent events, such as occurrences on radar screens, but even in active work the need to notice unusual events plays a major part. So far this year five railway-engine drivers have been blamed for accidents; perhaps experimental investigation of the causes would prove more profitable than the normal approach of punishment or exhortation.

Research in this field, too, can assist in the design of instruments; the efficiency with which a man notices a flashing signal may be a function of the duration of the flash; a man may suffer less from monotony if to inspect a dial he has to lift a sprung cover; signals may vary in frequency, intensity and duration; dials and screens can be arranged and designed to engender viewing efficiency.

With the growth of automatic techniques, the increase in the number of machines that one man has to mind, the centralisation of production control as in the famous Soviet piston factory, the greater is the need for systematic investigation of human vigilance. It is the methods of psychology that can best help in this respect.

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Weather and Fuel Demand

Britain's economy is so delicately balanced that even the weather can affect its equilibrium. This was brought out in a paper read before the Geography Section of the B.A. by Professor G. Manley of Bedford College, University of London. Notwithstanding oil supplies and the prospect of abundant electric power from atomic energy, the bulk of domestic heating requirements are to-day satisfied directly or indirectly by coal. Lighting, cooking and heating account for nearly a third of our total consumption. Nowadays we do not produce sufficient coal and our import is at present of the order of 10 million tons a year, or about 4 per cent. of our needs. Heating requirements for premises vary with the overall temperature of the "heating season," September to May. A long cold spring may thus impose a more serious total demand on our resources than will arise from a severe spell in January or February, although this attracts more public attention. Simple calculations show that the demand for heating in the long cool season of 1950 to 1951 was greater than in the dramatic winter of 1947.

Much research has already been carried out and it is shown that the difference in the demand for fuel imposed by a severe heating season is likely to be about 10 million tons—much the same as our present import. The irregular incidence of severe seasons is also demonstrated. Further research on climatic fluctuations is thus desirable as it now impinges directly on the balance of trade.

Representative statistics of overall temperature for the heating season are available for England for more than 250 years, although before 1800 they are likely to be less accurate. These enable the "heating demand" to be compared and indicate that 1821-22 was the mildest season; it was approached in 1948-49. The most severe seasons were 1739-40, 1813-14 and 1878-79; they provide a warning of what might happen again. The heating demand in late Victorian times was in several seasons considerably greater than in any season since 1900; in this century 1916-17 ranks worst, followed by 1950-51. Some confirmation of the early records is provided by observations of the frequency of snow. The amelioration since 1890 has been noteworthy.

In recent decades a tendency towards warmer springs and autumns has been manifest, but there are some slight signs that since 1950 a tendency for decline may have set in. While there is no obvious rhythm or periodicity, there is little reason to suppose that a most taxing combination of a severe winter and a cold spring may not at any time occur, against which fuel resources may need to be conserved.

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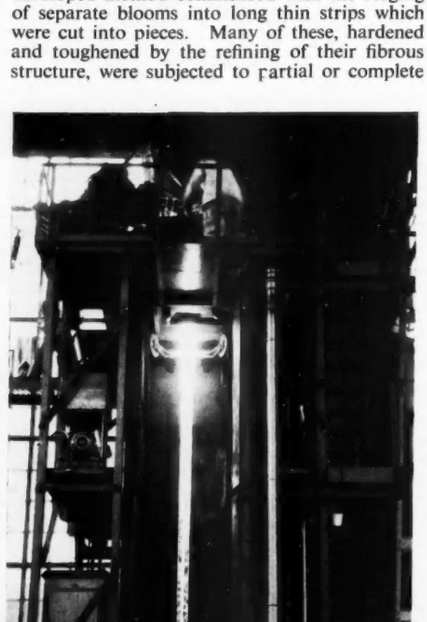
Sword Play

Not very long ago—a couple of centuries perhaps—the sword was still a serious weapon, of personal defence at least, and a product of the highest craftsmanship. A special interest in the craft of pattern welded iron swords was kindled in the Ancient Monuments Laboratory some years ago by the cleaning and examination of a sword from the Thames at Westminster, and a series of experiments were started this year to determine the manner in which these weapons were made. Last week, at the British Association meeting, Mr. J. W. Anstee of the Museum of English Rural Life, Reading University, discussed these experiments. They led to the conclusion that the cores of pattern welded swords were made by welding together a number of composite iron rods that had been separately twisted.

The experiments were carried out with simple forging gear, good wrought iron and one assumption. This was the possibility that angular striations could be made by twisting one strip with a cross-sectional ratio of three to one to such an extent that the channels of its double-start threads would be eliminated. Test strips invariably sheared before the grooves filled up. The obvious answer was to pack them with small filler rods. A three-piece composite rod was twisted, welded and etched, and particles of scale forced out of the twisted seams as the threads closed up. The removal of these oxides from internal surfaces was obviously vital to the success of the welds, and, similarly, the anvil had to be continually brushed clean as loose scale might cause deep indentations in the finished forging.

Further experiments seemed to lead to the conclusion that the technique behind the fully developed method commenced with the forging of separate blooms into long thin strips which were cut into pieces. Many of these, hardened and toughened by the refining of their fibrous structure, were subjected to partial or complete carburation. This, followed by twisting, forging and welding, toughened them still more. After the blade had been finished it might be exposed to further carburation, as the single-bar cutting edges had to be reasonably sharp. Presumably, the finished blade would have to be hardened and tempered if its carbon content were high enough.

In addition to reviving the technique, the series of eight experiments showed that it was possible to reproduce any chevron pattern by the simple process of twisting and grinding.



A spring-mounted mould is a distinguishing feature of the B.I.S.R.A. method of continuous casting. (See "Helping the Steel Industry.")

★ ★ ★

Helping the Steel Industry

Scientists are notoriously loath to tell you what they're doing until they've done it. This is sometimes a pity, for planning must always be carried out on a basis of probability, not certainty, and to know what work is currently in progress may often serve as a valuable guide. Clearly the British Iron and Steel Research Association believes in keeping its public in touch with its activities. Yesterday and to-day the B.I.S.R.A. laboratories in Hoyle-street, Sheffield, hold open days.

One recent development, which visitors could see in operation, was the B.I.S.R.A. process for continuously casting steel. Briefly, the molten steel is poured into a liquid-cooled bottomless copper mould—copper is chosen for its good heat conductivity—and as the metal solidifies it passes through the mould as an ingot, supported on the head of a ram; the ram initially closes the mould but as solidification proceeds it is gradually lowered. An impression of the process can be gained from an illustration on this page. The distinguishing feature of the B.I.S.R.A. method is the use of a spring mounting for the mould, which overcomes the tendency of the cast ingot to rupture near the mould walls. This might occur at the top of the ingot, as the ram lets it down, at a point when some solidification had taken place, with consequent adhesion to the walls, but insufficient either to contract the ingot from the mould or to give strength to the ingot where it was retained. In the B.I.S.R.A. plant, when this happens, the mould moves down with the ingot, so compressing the springs. At a point where the metal is sufficiently solid to resist fracture, the compression of the springs is just enough to force the mould from the ingot. During correct operation, therefore, the mould moves up and down. Advantages claimed for the system are that small sections can be produced without cogging; hot billets may pass directly to the finishing mill without reheating; the plant requires less space than normal casting installations; and there is less scrap.

Another technique which has been devised by B.I.S.R.A. is the rapid heating of ingots before forging. It is claimed that by using two furnaces—a preheater at 1,000 deg. C. and another furnace at 1,250 deg. C.—ingots of high-speed steel have been satisfactorily forged after total heating times (from cold) of 30 minutes for 4 in. square ingots and 45 minutes for 6 in. square ingots. In addition to increased speed, the quick-heating method gives reduced scale losses.

A means of controlling the length of stroke of a forging press electrically by a potentiometer device has been developed, so that a billet can be squeezed to a pre-set thickness with an error of as little as $\frac{1}{64}$ in., so minimising time wasted in preliminary squeezing. To study the effect of interaction between stands of tandem rolling mills, a model of a three-stand tandem mill has been built in which gauge control of the rolled strip is achieved automatically. Radioactive isotopes have been used to measure the extent of furnace-wall erosion, to trace the movement of different materials in furnaces, and to determine blast-furnace gas flow. These and other studies are in progress at B.I.S.R.A. laboratories; they represent processes and methods which may soon be commonplace and are thus a guide to the future of the iron and steel industry.

Equipment and staff from Greenwich Observatory are to be transferred to Herstmonceux where new buildings are approaching completion.

AUTOMATIC ASTRONOMY

ROYAL GREENWICH OBSERVATORY ANNUAL REPORT

The use of automatic and electronic devices to assist astronomical observation and computation is expanding rapidly according to the latest annual report on the Royal Greenwich Observatory. The report covers the period April 1, 1955 to March 31, 1956 and is signed by Dr. Richard van der Riet Woolley, F.R.S., who succeeded Sir Harold Spencer Jones as Astronomer Royal on his retirement at the end of last year. Routine work at the Observatory's establishments has continued and there has been notable progress on the buildings under construction at Herstmonceux to house the equipment and staff transferred from Greenwich. Construction of the new magnetic observatory at Hartland, to replace the one now at Abinger, was started last summer and is proceeding satisfactorily. At Herstmonceux the erection of the photographic zenith tube was completed during the year and the installation of the Cooke transit circle is actively in hand. Preparations for the International Geophysical Year,* however, are, somewhat unexpectedly, not mentioned in this report.

The application of electronic and automatic techniques is exemplified, in the case of the Cooke transit instrument, by newly designed apparatus for controlling the exposures and advancing the films of the circle-reading cameras from accessible central control points; and by two Hollerith automatic punches; one for recording the circle readings of a semi-automatic film-measuring micrometer, the other for recording transit times in conjunction with a dekatron counter. In the circle-reading cameras themselves, of which there are 14, the fiducial wires near the focal planes are being replaced by photo-etched glass graticules. The new transit installation also includes a two-pen tape chronograph driven by a synchronous motor. Other punched-card techniques are being extensively employed for analysing observations made in past years with the Airy transit circle at Greenwich, and for computing the proper motions of stars.

LONGITUDE AND LATITUDE

After several months of adjustment and rectification the photographic zenith tube is now in regular use at Herstmonceux for time and latitude determinations. These include the first precise measurements of the astronomical longitude and latitude of the new site of the Observatory, the provisional value for the longitude of the photographic zenith tube itself being 1 min. 21·091 sec. east of the prime meridian defined by the position of the Airy transit circle at Greenwich. When allowance is made for the deflections of the vertical at the two stations (deduced from gravity data), this value is consistent with the longitude given by the Ordnance Survey, the zero meridian of which is known to differ by 0·02 sec. from the Airy transit meridian. The provisional value for the latitude of the photographic zenith tube is +50 deg., 52 min., 17·75 sec., with no allowance for the current value of the earth's polar motion.

When the photographic zenith tube is being used the times of observations are recorded by Strobotron flashing lamps, thus providing the so-called clock error. Until recently these clock errors were referred to a pendulum clock at the Observatory. They will, as soon as possible, be referred to more precise quartz oscillator clocks when the latter have been installed at Herstmonceux. Meantime a Post Office telephone line has been rented so that second impulses from the phonic motor output of a quartz crystal clock at Abinger are used to control the Strobotron lamps. Time determinations are thus referred directly to the clock with practically no risk of the results being affected by any diurnal variation of rate. There persists, however, the possibility of variation in the lag of the Post Office line. The lag is, accordingly, regularly checked by comparing the remote clock against the simultaneous reception, at Herstmonceux and Abinger, of the 10 hour GBR time signal broadcast from Rugby. Incidentally, a new type of long-wave receiver for the 16 kilocycles per second Rugby time signal, incorporating modern components, has been constructed and is in full use at Abinger. This improved model has the advantages of compactness and simplicity, and two similar receivers will be built for use at Herstmonceux. Other apparatus has been assembled for continuously recording, with an accuracy of a few parts in 10^{10}, the phase differences and frequencies of the 16 kilocycles per second and 60 kilocycles per second controlled transmissions from Rugby.

Throughout the year the Observatory time service has been maintained. Quartz clocks at several co-operating stations have been useful in this work but the principal long-period standards are ring crystal oscillators. One "working" clock has been fitted with an adjustable condenser in its control circuit to meet an increasing demand for short-period accuracy. The modification has proved so successful that provision is being made for the attachment, if required, of a variable condenser to each of the quartz clocks to be installed at Herstmonceux. Research of a more fundamental character, directed to the increased precision of time measurement, is being actively pursued. A most interesting investigation of this type, now in progress at Oxford with the help of the Clarendon Laboratory, is an exploration of the improved stability of a quartz resonator which may be achieved by operating it at the temperature of liquid hydrogen. Results so far obtained suggest that the "Q" factor of the resonator can be increased at least five-fold, and even better performance may be obtained when the low-temperature and electronic measuring equipment has been modified in the light of the experience already gained. Developments in the present thermostatic control system for oscillators are exemplified by the incorporation of a transistor amplifier in the oven control circuit.

As compared with a thermionic valve amplifier no loss in accuracy of temperature control can be detected by instruments sensitive to ±0·001 deg. C. A stabilised magnetic amplifier has since been developed as another alternative, making it possible in favorable circumstances to dispense altogether with valves in the control unit, with the added advantage of greatly reduced power consumption. As a final example of research on quartz clocks, mention should be made of a new method of adjusting and checking the phase of the maintaining amplifier without stopping the oscillator. An amplifier equipped with this device has shown, over a period of four months, phase variations of less than 0·17 deg., which correspond to frequency changes not exceeding one part in 10^{11}.

RASH OF SUNSPOTS

The Observatory's routine records of the magnetic elements, maintained at Abinger throughout the year, continue the trends of previous years and display no remarkable feature. The usual meteorological data have also been obtained, though with the omission, since the beginning of 1956, of one of the regular daily series of observations, on account of staff conditions. Two outstanding features of these records are the fine weather of last summer which enabled photographs of the sun to be taken on 308 days; and the extraordinary cosmic ray flare of February 23, which temporarily more than doubled the measured cosmic radiation flux and produced a sudden diminution of the night-time level of atmospherics. Solar activity is rising steeply just now and monthly sunspot numbers have averaged 100 during the first three months of 1956. Twenty-five sunspots, each of area greater than 500 millionths of the sun's hemisphere, have appeared during the year under review, compared with only three such spots during the previous 12 months.

The report ends with a short reference to the projected Isaac Newton Observatory, for which a 98 in. telescope is still under discussion. The board of management unanimously agreed, at a meeting last March, that the "duplex" design should be abandoned in favour of a conventional paraboloid telescope. A newly elected executive committee has already made substantial progress in working out a design along these lines.

* * *

CLEAN AIR ACT

The Clean Air Act, which went on to the Statute Book on July 4, 1956, is a comprehensive measure of 37 sections and four schedules. The National Smoke Abatement Society has just published a Summary of the Act, which, as a 12 page booklet, describes and explains the Act in a handy form for general reference.

The booklet is available from the Society at Palace Chambers, Bridge Street, London, S.W.1, at 6*d.* for single copies, or 4*s.* 6*d.* per dozen, postage included.

* ENGINEERING vol. 180, page 296, 1955.

QUANTITIES IN BATCH PRODUCTION

ARRANGING MANUFACTURING PROCESSES TO GIVE MAXIMUM RETURN

By Samuel Eilon, PH.D., DIPL.ING., B.SC.(ENG.), D.I.C., A.M.I.PROD.E.*

The question of lot size in batch production is discussed and a formula for a minimum-cost lot size is suggested for a single product and for the case of a number of products. Deviations from the desired quantity are sometimes required, due to difficulties in multi-product scheduling. The minimum-cost lot size may not always be the most suitable and other lot sizes are analysed, such as the economic lot size and lots corresponding to maximum absolute profit and to highest ratio of profit to investment.

Notation

B	Average storage costs per piece per unit time	m	Cost of materials
I	Carrying costs per piece per unit time $= i\,c$	n	Number of products scheduled
I_e	Carrying charges per piece per unit time $= (i + r)\,c$	o	Overheads
K	Carrying costs factor	p	A ratio $= \frac{Y - c}{Y_m - c}$
Q	Quantity produced	p'	A ratio $= \frac{Y' - c}{Y_m - c}$
Q_e	Economic lot size	q	The ratio of quantity produced to the minimum-cost lot size $= \frac{Q}{Q_m}$
Q_m	Minimum-cost lot size	r	Rate of return expected on the invested capital (expressed in the same manner as i)
Q_p	Maximum-profit lot size	s	Preparation costs, including machine set-up
Q_o	Minimum stock	t	Interval time between two production periods
T_c	Consumption period	t_s	Setting and preparation time before production
T_p	Production period	z	Ratio of profit to investment
Y	Total costs (or charges) per piece	α	Ratio of consumption rates $\left(\text{for example, } \frac{a_{c2}}{a_{c1}}\right)$
Y_e	Charges per piece when Qe is produced	γ	The ratio $\frac{a_c}{a_p}$
Y_m	Minimum costs per piece		
Y′	Sales price		
Z	Profit		
a_c	Consumption rate, units per unit time		
a_p	Production rate, units per unit time		
a'_p	Rate of increase of stock during the production period, units per unit time		
c	Constant costs per piece $= m + l + o$		
i	Interest rate per unit time (expressed decimally)		
l	Cost of labour		

Other symbols are explained in the text.

Introduction

Batch production is a common feature in industry. It arises mainly because of limited demand for certain products as compared with the high rate at which they can be produced. As the production of each batch or lot involves certain preparations and machine setting, it is desirable from the technical point of view to have long and smooth runs. The production of excessively large lots, however, results in a slow turnover of capital, in large carrying costs due to interest and in storage charges, thus leading to higher total production costs. The choice of lot sizes is a basic problem in batch production, especially when many products are manufactured and when the scheduling problems become rather involved.

Batch production in its simplest form is shown in Fig. 1, where the stock (Q) is plotted against time (T). The line 0-1 represents the production process, which is carried out at the rate of a_p units per unit time. After a production period T_p the level of stock reaches Q_1, when production stops. The stock, decreasing now by the consumption rate a_c units per unit time, is represented by the line 1-2, and after a consumption period Tc, no stock is left and the production starts again at point 2. The same cycle can now be repeated, unless it is intended to produce a quantity Q_2, which is different in magnitude from Q_1. During the time T_c the equipment can be utilised for producing other products. It can be shown from the diagram that the relationship between the various factors mentioned may be expressed as

$$Q_1 = a_p T_p = a_c T_c \quad . \quad . \quad (1)$$

The lines 0-1 and 1-2 in Fig. 1 represent uniform rates of production and consumption, and while in many cases a_p will remain reasonably constant during the production period, the rate of consumption may vary. These variations may be independent of the stock and be related to some external factors (seasonal demands, weather conditions, etc.), sometimes causing intermittent consumption. Two variations which are related to the level of stock are shown in Fig. 2. Line 1-3 represents the state of affairs when the rate of consumption increases as the stock diminishes. This situation may arise when a product has been exceptionally successful in capturing the confidence of the consumer, or sometimes in a market where demand exceeds supply. The consumption period T'_c in this case would be shorter than the time T_c, which would have resulted had the initial rate of consumption continued uniformly throughout. A different situation is represented by the line 1-4, where the rate of consumption dwindles with time, as for instance in a market flooded with competitive products, when it becomes harder and harder to satisfy the customer or offer him exactly what he wants. The consumption period T''_c in this case will be appreciably longer than Tc. Situations such as these may sometimes be represented by the expression $Q = A + BT^m$ (where A and B are constants) and have to be thoroughly analysed before formulae for economic lot production can be successfully applied.

Usually batch production does not follow the pattern of Fig. 1 even when the consumption is linear. To facilitate availability of the product on the market, it is required to have a new stock (Q) at point 3, when the old stock is completely consumed (Fig. 3). This means that production must start at point 2_1, so that the distance 2_1-2 equals the production period T_p. At time 2_1 the number of articles in stock is indicated by the ordinate Q_0. Lines 0-1 and 2-3 in Fig. 1 represent the increase in stock purely by the rate of production a_p, whereas in fact the stock diminishes simultaneously by the consumption rate a_c. As both these rates are linear, the overall change in stock level will be represented by the heavy line $2' - 3$ in Fig. 3. Thus the stock changes are shown by lines 0′-1, 1-2′, 2′-3, etc. This pattern is similar to that of Fig. 1, only the horizontal axis is indicated here at a distance of Q_0 from 0T. The consumption rate remains a_c as before, while the rate of building up the stock a'_p is

$$a'_p = a_p - a_c.$$

The interval time available for utilising the equipment for other purposes is

$$t = T_c - T_p \quad . \quad . \quad . \quad (2)$$

where t includes the setting time required for preparing the machines before the production period T_p. From the diagram it can be shown that

$$Q = a_p T_p = a_c T_c$$

and

$$Q_0 = a_c T_p$$

Thus

$$\frac{Q_0}{Q} = \frac{a_c}{a_p} = \frac{T_p}{T_c} = \gamma \quad . \quad . \quad (3)$$

and

$$t = T_c (1 - \gamma) \quad . \quad . \quad (2a)$$

Minimum Cost Lot Size

The production costs per piece consist mainly of four factors: (i) constant costs per piece c, which include materials (m), labour (l) and overheads (o) ($c = m + l + o$); (ii) preparation costs s per lot, which include drawings, planning, setting-up of machines and equipment, etc. $\left(\text{the costs per piece are } \frac{s}{Q}\right)$; (iii) carrying costs due to interest paid on the money invested in articles kept in stock, $I = i\,c$, for one piece per unit time $\left(\text{the average level of the stock during the consumption period } T_c \text{ is } \frac{Q + Q_0}{2}\right)$, thus the carrying costs for the stock for this period are $I \frac{Q + Q_0}{2} T_c$; substituting $T_c = \frac{Q}{a_c}$ and dividing by Q, the carrying costs per piece are $\frac{I}{a_c} Q (1 + \gamma)\Big)$; and (iv) average storage costs per piece for the consumption period T_c $\left(\text{these are } B\,T_c \text{ or } \frac{BQ}{a_c}\right)$.

These factors are shown in Fig. 4 and the total costs per piece are

$$Y = c + \frac{s}{Q} + \frac{Q}{2a_c}[I (1 + \gamma) + 2B] \quad (4)$$

The last two factors can be combined into total carrying costs and denoted by K Q, so that

$$K = \frac{I (1 + \gamma) + 2B}{2a_c} \quad . \quad . \quad (5)$$

and

$$Y = c + \frac{s}{Q} + KQ \quad . \quad . \quad (6)$$

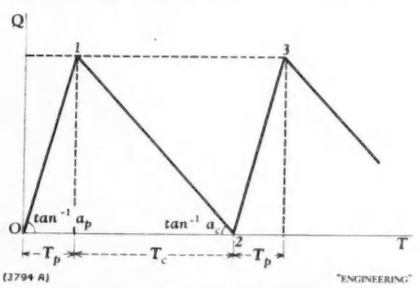


Fig. 1 Batch production in its simplest form as represented by the relationship between stock in hand (Q) and time (T). The lines 0-1 and 1-2 represent production and consumption periods, respectively.

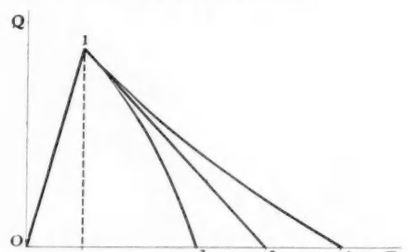


Fig. 2 Consumption may vary as the level of stock falls. Line 1-3 represents an increasing rate of consumption as stock diminishes, as when a product captures the confidence of the consumer, and line 1-4 a falling consumption rate.

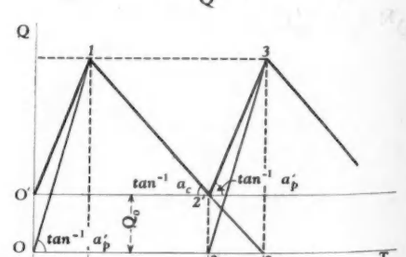


Fig. 3 If the product is to be continuously available then it is necessary to have a new stock (Q) ready at point 3, when the old stock has been consumed.

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The point where costs per piece are a minimum is found by

$$\frac{dY}{dQ} = -\frac{s}{Q^2} + \frac{1}{2a_c}[I(1+\gamma) + 2B] = 0$$

or

$$Q_m = \sqrt{\frac{2a_c s}{I(1+\gamma)+2B}} = \sqrt{\frac{s}{K}} \quad . \quad (7)$$

It is noteworthy that at the point Q_m the total carrying costs per piece and the preparation costs per piece are equal, as

$$K Q_m = \frac{s}{Q_m} \quad . \quad . \quad . \quad (8)$$

The minimum costs are, therefore,

$$Y_m = c + \frac{2s}{Q_m} = c + 2K Q_m \quad . \quad (9)$$

When $B \ll I$ and $\gamma \ll 1$ the lot for minimum cost may be written as

$$Q_m = \sqrt{\frac{2a_c s}{I}} \quad . \quad . \quad . \quad (10)$$

This formula was first suggested by Camp in 1922 and will give a satisfactory estimate for Q_m under the circumstances.

Expression (7) does not include some factors which may affect the value of Q_m, such as the effect of dividing a lot into a number of batches, the time factor involved in waiting from one process to another, etc. These factors were incorporated in a formula suggested by F. E. Raymond, which in its simplified version reads

$$Q_m = \sqrt{\frac{2a_c s}{\left[I\left[2F - \gamma\left(1-\frac{1}{N}\right)\right] + I\gamma\frac{2k}{A} + \frac{2bv}{h}\left[1-\gamma\left(1-\frac{1}{N}\right)\right]\right]}} \quad . \quad . \quad . \quad (11)$$

where F = a stock coefficient, being the ratio of the average number of articles in the stock above Q_0 to the maximum number above Q_0; for uniform consumption F = 0·5;

$k = \frac{c'}{c} = \frac{1}{2}\frac{m+c}{c}$;

c' = cost of batch in process = $m + \frac{1}{2}(l+o)$.

v = volume storage per piece (cub. ft.)

b = storage costs per sq. ft.

h = average height to which storage is permitted

N = number of workings or batches in one lot

A = time factor = $1 + (N-1)\frac{T_{0p_1}}{T_{p_1}}$

T_{0p_1} = time for first operation in the batch

T_{p_1} = total process time for first working or batch

Although the inclusion of all these factors in a complex formula may be theoretically desirable, in many cases the results obtained by the use of the simpler expression (7) would be quite satisfactory, especially as many factors which appear in the formula cannot usually be accurately determined and have to be estimated from previous experience, market research, etc. The use of specialised and complex formulae would be justified only when the number of workings is large or in special circumstances.

In the case when one batch is produced in a lot (i.e. N = 1), it can be shown that Q_m derived from (7) will be slightly higher than Q_m derived by Raymond's formula, while the estimate of Q_m by Camp's formula (10) will be the highest of the three (the error incurred by the use of Camp's formula depends on the values of a_p and B, as pointed out above). As seen from Fig. 4 the curve Y is "flat" in the vicinity of the minimum point, being much "flatter" to the right of the minimum than to the left. A slight over-estimate of Q_m, such as obtained by formula (7), will not cause a substantial increase in the costs per piece.

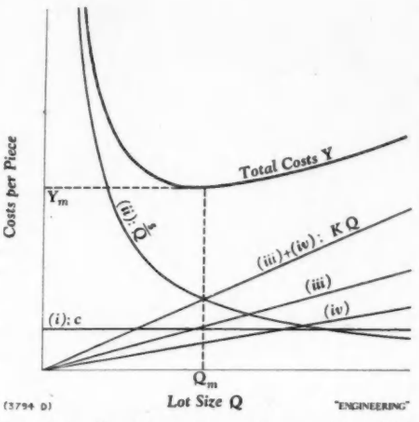


Fig. 4 Production costs per piece consist mainly of four factors: constant costs per piece, preparation costs per lot, carrying costs for held stock, and average storage costs per piece for the consumption period. Total costs are also shown.

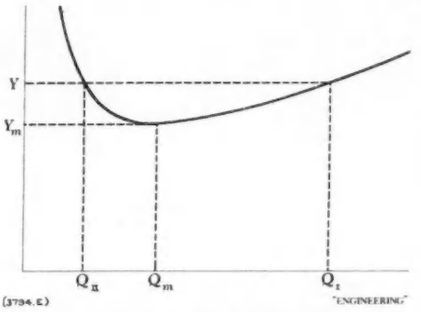


Fig. 5 Total costs per piece plotted against quantity produced, showing minimum cost per piece (Y_m). Provided that the costs Y are not exceeded, the corresponding lot size will lie between Q_I and Q_{II}, thus introducing flexibility into the production schedule.

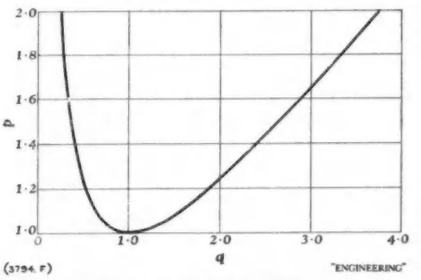


Fig. 6 Graphical relationship between p and q (see section on notation) by means of which Q_I and Q_{II} (see Fig. 5) may be estimated.

It should also be noted here that the minimum cost lot-size also offers the highest ratio of profit to capital invested. If the sales price is Y′, the profit Z is $Z = Q(Y' - Y)$ and the ratio of profit to investment is $z = \frac{Z}{QY} = \frac{Y'}{Y} - 1$. This ratio is maximum when Y is minimum, or when Q_m is produced.

Economic Lot Size

It has been pointed out by F. E. Raymond and P. T. Norton that lot production at minimum costs per piece is not the most economic, if the highest rate of return on the capital is sought. The reason lies mainly in the fact that I in the above formulae is related to the interest paid on the capital, and not to the desirable rate of capital turnover. In fact it is possible to produce a smaller quantity than Q_m which will still yield the same rate of return as Q_m, but will require less capital. If the rate of return at the point Q_m is acceptable, any point lying between the two quantities (called by Raymond "the economic range") may be selected, thus offering flexibility in manufacture.

The point of maximum return (called the economic lot size Q_e) lies in the middle of this range and can be found by formula (7), in which I is simply substituted by $I_e = (i + r)c$. Y in (4) and Fig. 4 will now represent the total charges per piece, which ensure a proper rate of return. Hence

$$Q_e = \sqrt{\frac{2a_c s}{I_e(1+\gamma)+2B}} = \sqrt{\frac{s}{K_e}} \quad . \quad (7a)$$

It should be noted here that in this approach some factors were excluded for the sake of simplicity, such as the return on the money invested in preparation before production. The costs per piece when Q_e is produced are higher than those achieved with Q_m, but the turnover of the capital is quicker.

Deviations from Q_m (or Q_e)

Due to technical difficulties in scheduling, it is not always possible to produce the desired minimum cost quantity Q_m (or the most economic lot Q_e, if this is aimed at; the following arguments apply equally to both cases). Supposing a deviation from Q_m is permissible, provided the costs Y are not exceeded (see Fig. 5), the corresponding lot size will lie between the limits Q_I and Q_{II} and flexibility is thus introduced into the production schedule. Q_I and Q_{II} can be found from

$$p = \frac{Y-c}{Y_m - c} = \frac{\frac{s}{Q} + KQ}{2KQ_m} = \frac{1}{2}\left[\frac{s}{K}\frac{1}{QQ_m} + \frac{Q}{Q_m}\right].$$

Substitute

$$\frac{s}{K} = Q_m^2 \text{ and } q = \frac{Q}{Q_m}:$$

$$2p = \frac{Q_m}{Q} + \frac{Q}{Q_m} = \frac{1}{q} + q. \quad (12)$$

or

$$q = p \pm \sqrt{p^2 - 1} \quad . \quad . \quad (13)$$

This relationship is shown in Fig. 6 where two values of q are obtained for a known value of p.

Highest-Profit Lot Size

In many cases the selling price of a product is not so much determined by the production costs as by conclusions from market research or by the conditions prevailing in the competitive market. Indeed, in many cases the first analysis undertaken by a manufacturing enterprise is to determine whether the production of a specific article, which can be sold at a known maximum price, should be undertaken. In such cases the aim may sometimes be the achievement of the maximum profit Z for the manufactured lot.

$$Z = Q(Y' - Y)$$

The profit is denoted in Fig. 7 by the shaded rectangle, which represents the difference between the money earned (rectangle Y′ − Q) and the cost of production (rectangle Y − Q), when a lot consisting of Q articles is being produced. Maximum profit will be achieved when

$$\frac{dZ}{dQ} = Y' - \frac{d(QY)}{dQ} = 0$$

If Q_p is the highest profit lot size, and Y′, Y are substituted from (6),

$$\frac{s}{Q'} + KQ' - 2KQ_p = 0$$

Therefore

$$Q_p = \frac{1}{2}\left[\frac{s}{KQ'} + Q'\right] = \frac{Q_m}{2}\left(\frac{Q_m}{Q'} + \frac{Q'}{Q_m}\right)$$

But by (12),

$$\frac{Q_m}{Q'} + \frac{Q'}{Q_m} = 2p'$$

where Q′ may relate either to Q'_I or Q'_{II} and

$$p' = \frac{Y' - c}{Y_m - c}$$

Therefore

$$Q_p = p' Q_m \quad . \quad . \quad (14)$$

Q_p can be graphically obtained by joining point c on the Y axis with the point of minimum on the Y curve (Fig. 7). The intersection of this line with the horizontal line Y yields the desirable point P, the horizontal co-ordinate of which is Q_p.

While most economic lot Q_e is smaller than Q_m, the quantity corresponding to maximum absolute profit Q_p is higher than Q_m (since $p' > 1$). The question which of these three lot sizes should be aimed at depends on the circumstances and on management policy. But even in the case when the most economic lot Q_e is preferred, it is sometimes desirable to aim at the highest possible absolute profit under the circumstances, whereby the best lot size to choose would be

$$Q_p = p' Q_e \quad . \quad . \quad (15)$$

p' in this case being defined as $p' = \dfrac{Y' - c}{Y_e - c}$

Q_p would be higher than Q_e, where the total charges per piece for the desired capital turnover are minimum, but the increase in these charges incurred by producing Q_p would generally be relatively small.

Scheduling Two Products

If two products are scheduled for production with the same equipment, such that the interval time t_1 after production of the first product is fully utilised in the production of the second product and in preparations, the sequence of operations can be described as follows: (i) setting up of machines and preparations for production of first product = t_{s_1}; (ii) production period of first product = T_{p_1}; (iii) setting up of machines and preparation for production of second product = t_{s_2}; (iv) production period of second product = T_{p_2}; (v) setting and preparation for production of first product = t_{s_1}; etc.

The interval times t_1, t_2 as defined by (2) and shown in Fig. 8, can be expressed by:

$$t_1 = T_{c_1} - T_{p_1} = t_{s_2} + T_{p_2} + t_{s_1}$$
$$t_2 = T_{c_2} - T_{p_2} = t_{s_1} + T_{p_1} + t_{s_2}$$

or

$$t_1 - t_2 = T_{c_1} - T_{c_2} - T_{p_1} + T_{p_2} = T_{p_2} - T_{p_1}$$

Therefore

$$T_{c_1} = T_{c_2} = T_{p_1} + T_{p_2} + t_{s_1} + t_{s_2}$$

The equality of the two consumption periods ensures that the two products are always available on the market and that stocks are replenished to the same level each cycle. The above condition also expresses the full utilisation of the equipment from the time point of view. If (1) is substituted, the ratio between the two lots depends on the ratio of the consumption rates, which will be denoted by α:

$$\frac{Q_2}{Q_1} = \frac{a_{c_2}}{a_{c_1}} = \alpha \quad . \quad . \quad (16)$$

Rates of consumption depend on the circumstances prevailing in the market and cannot be affected by scheduling procedures. The ratio α is thus fixed; but on the other hand the values of Q_1 and Q_2 are determined by (7) or (7*a*). In order to satisfy all these requirements

$$\frac{Q_2}{Q_1} = \alpha = \sqrt{\frac{K_1 s_2}{K_2 s_1}}$$

The chances that this condition can be satisfied in practice are very small indeed, and it is therefore desirable to find a compromise that will strike the best balance as far as the final result of producing the two products is concerned. If the policy is adopted that the two products must always be available on the market, i.e., that

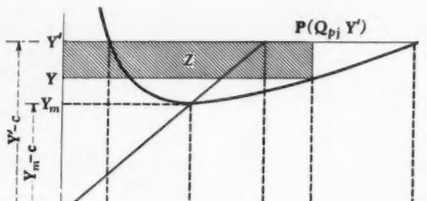


Fig. 7 Total costs plotted against quantity produced. The shaded rectangle, denoting the difference between the money earned and the cost of producing Y articles, represents the profit.

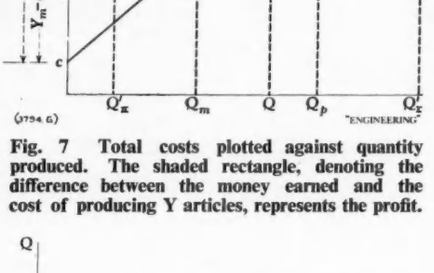


Fig. 8 Quantity produced (Q) plotted against time (T) for a multi-product schedule.

$T_{c_1} = T_{c_2}$, the lot sizes Q_1 and Q_2 may deviate from the ideal values (calculated by (7) or (7*a*) when each individual product is considered) so that the best desirable result is achieved. In some cases the criterion for best results may be defined by the maximum combined absolute profit.

$$Z = Q_1 (Y'_1 - Y_1) + Q_2 (Y'_2 - Y_2)$$

Substituting (6) and (16):

$$Z = s_1 \left(\frac{Q_1}{Q'_1} - 1\right) + K_1 (Q'_1 Q_1 - Q_1^2) + s_2 \left(\frac{Q_1}{Q'_2} - 1\right) + K_2 (Q'_2 \alpha Q_1 - \alpha^2 Q_1^2) \quad . \quad . \quad (17)$$

Maximum profit is achieved when

$$\frac{dZ}{dQ_1} = \frac{s_1}{Q'_1} + K_1 Q'_1 - 2 K_1 Q_1 + \frac{s_2 \alpha}{Q'_2} + K_2 \alpha Q'_2 - 2 K_2 \alpha^2 Q_1 = 0$$

Substituting

$$q_1 = \frac{Q_1}{Q_{1m}}; \quad q_2 = \frac{Q_2}{Q_{2m}}; \quad \frac{Q_{2m}}{Q_{1m}} = \alpha_m$$

$\left(\text{or } q_1 = \dfrac{Q_1}{Q_{1e}}; \quad q_2 = \dfrac{Q_2}{Q_{2e}}; \quad \dfrac{Q_{2e}}{Q_{1e}} = \alpha_m \text{ if the desired return on the investment is to be reasonably incorporated}\right)$,

$$q_1 = \frac{K_1 p'_1 + \alpha \alpha_m K_2 p'_2}{K_1 + \alpha^2 K_2} \quad . \quad (18)$$

and

$$q_2 = \frac{\alpha_m}{\alpha} q_1 \quad . \quad . \quad . \quad . \quad (19)$$

where

$$p'_1 = \frac{Y'_1 - c_1}{Y_1 - c_1}; \quad p'_2 = \frac{Y'_2 - c_2}{Y_2 - c_2}$$

Y'_1, Y'_2 being the selling prices for products 1 and 2 respectively.

Multi-Products Scheduling

In a similar fashion it is possible to find the appropriate lot sizes when n products are scheduled for production. Quantity produced (Q) plotted against time (T) for a multi-product schedule is shown in Fig. 8. Again the assumptions are that each product should always be available on the market and that the time is fully utilised either in production or preparations for it. It can be shown that

$$Tc_1 = Tc_2 = \ldots = Tc_n$$

or $Q_n : Q_{n-1} : \ldots : Q_2 : Q_1$
$= a_{c_n} : a_{c_{n-1}} : \ldots : a_{c_2} : a_{c_1}$
$= \alpha_n : \alpha_{n-1} : \ldots : \alpha_2 : \alpha_1$

where the ratios α are determined by the rates of consumption (α_1 being equal to 1) and known either from previous experience or market research. Similarly, the following ratios are known

$$Q_{nm} : Q_{n-1m} : \ldots : Q_{2m} : Q_{1m} = \alpha_{nm} : \alpha_{n-1m} : \ldots : \alpha_{2m} : \alpha_{1m}$$

where $\alpha_{1m} = 1$

The total profit is given by

$$Z = \sum_1^n Q (Y' - Y) = \sum_1^n \left[s \left(\frac{Q}{Q'} - 1\right) + K (Q Q' - Q^2)\right] = \sum_1^n \left[s \left(\frac{Q_1 \alpha}{Q'} - 1\right) + K (\alpha Q_1 Q' - \alpha^2 Q_1^2)\right] \quad . \quad . \quad . \quad (17a)$$

Maximum profit will be achieved when

$$\frac{dZ}{dQ_1} = \Sigma \left[\frac{s \alpha}{Q'} + K \alpha Q' - 2 \alpha^2 Q_1 K\right] = 0$$

(where the symbol Σ denotes $\sum_1^n$).

or

$$Q_1 = \frac{1}{2 \Sigma \alpha^2 K} \Sigma \left(\frac{s \alpha}{Q'} + K \alpha Q'\right)$$

Substitute $s = K Q^2_m$

$$Q_1 = \frac{1}{2 \Sigma \alpha^2 K} \Sigma \left(\frac{K \alpha Q^2_m}{Q'} + K \alpha Q'\right)$$

$$q_1 = \frac{Q_1}{Q_{1m}} = \frac{1}{2 \Sigma \alpha^2 K} \Sigma \alpha \alpha_m K \left(\frac{1}{q'} + q'\right)$$

or, by use of (12),

$$q_1 = \frac{\Sigma \alpha \alpha_m K p'}{\Sigma \alpha^2 K}$$

and similarly $q_2, q_3, \ldots, q_n$ can be computed.

If on the other hand the maximum ratio of profit to capital invested is desirable, then

$$z = \frac{Z}{\Sigma Q Y} = \frac{\Sigma Q Y'}{\Sigma Q Y} - 1 = \frac{\Sigma \alpha Y'}{\Sigma \alpha Y} - 1$$

This ratio becomes maximum when $\Sigma \alpha Y$ is minimum, or when

$$\frac{d \Sigma \alpha Y}{dQ_1} = 0 = \frac{d}{dQ_1} \left[\Sigma \alpha c + \frac{s}{Q_1} + \Sigma \alpha^2 K Q_1\right]$$

thence

$$Q_1 = \sqrt{\frac{\Sigma s}{\Sigma \alpha^2 K}}$$

These final results give the best solution, either when maximum absolute profit or when maximum ratio of profit are desirable and when it is necessary to produce all n products. This optimum solution will be achieved even when some of the products will not contribute their proper share in the total profit, or may even cause a loss. To arrive at a better solution a further analysis has to be undertaken, where the production costs (or charges) per piece of each product and its share in the total profit are found. Alternative scheduling, either by dropping the unprofitable products or by introducing new possible products instead, can then be examined with the aim of selecting the best programme.

Bibliography

[1] Norton P. T. "Economic Lot Sizes in Manufacturing," *Mechanical Engineering*, vol. 55, page 608, 1933.

[2] Raymond, F. E. "Economic Production Quantities," *ASME Trans.*, vol. 50, MAN-50-10.

[3] Raymond, F. E. *Quantity and Economy in Manufacture*, McGraw-Hill, 1931.

At a later date we hope to publish a second article by Dr. Eilon dealing with "Economic Lot Sizes in Batch Production."

WOOD PLANING PROBLEMS

An investigation covering some of the problems associated with the planing of wood is being carried out at the Princes Risborough Laboratory of the Forest Products Research Board and some particulars of the work, and results obtained, are given in the report of the Board for the year 1955. In normal practice, wood is planed by a rotating cutter which removes horn-shaped chips. The cutting edges are engaged with the wood for only a small portion of each revolution of the cutter and not only does the depth of penetration increase from zero at entry to a maximum at the cutter exit, but also the direction of cutting changes relative to the grain of the wood. In these complicated circumstances it is exceedingly difficult to observe the actual behaviour of the wood during the cut, or to measure the forces exerted by the cutter.

Although the chip formation can be seen by using a stroboscope, or still pictures at various stages obtained with flash photographs, it was considered that, to build up an accurate analysis of the action of rotary cutting, it was necessary to simplify the conditions and accordingly investigations with rectilinear cutting at various directions of the grain of the wood were carried out. A typical photograph of chip formation is given in Fig. 2 below. Devices are to be added measuring the forces involved at different depths of cut and cutting angles. Some information on the net power demand in planing with a rotary cutter was obtained in another investigation covering six different species of timber at feed speeds ranging from 20 to 60 ft. per minute. The relation between power and feed speed appeared to be linear over the range tested. When the energy consumption per unit area cut was calculated and plotted it was seen that the cutting energy decreased as the rate of feed was increased.

A further research dealt with the blunting of planer cutters. Information relating the sharpness of the cutting edge to the nature and amount of wear has been obtained. The work was carried out with high-speed steel cutters with various sharpness angles planing equal runs of beech under the same conditions of spindle and feed speeds, cutting angle and depth of cut. The results obtained, expressed in terms of cutter wear, are shown in the curve given in Fig. 1. Silhouettes, × 100, of the cutter edges after planing 7,000 ft. of beech at 30 deg. cutting angle are shown in Fig. 3. The original edges of the cutter are indicated by the broken lines. It will be seen from these figures that the blunting increases slowly as the angle is reduced from 55 deg. to 35 deg. and then rapidly with further reduction to 25 deg. Edges with this last angle were weak and the effects of the fractures were visible on the wood surface after only 100 ft. of stock had been planed.

The angle most commonly used in practice is 35 deg. and it would appear from the curve that this is a transition point between cutters capable of giving good service and those having weak edges liable to fracture and blunt quickly. Beyond 35 deg. the curve rises so rapidly that a reduction of 2 or 3 deg. in this angle, which might occur in commercial sharpening, could result in considerable lowering of the cutter performance and be the cause of rapid blunting otherwise inexplicable. It is suggested in the report that 35 deg. is not quite suitable for practical use, as is shown by the frequent behaviour of cutters on hand-feed surfacing machines. When freshly ground and honed their edge life is noticeably shorter than that obtained after they have been re-sharpened by honing on the block when their sharpness angle is automatically made slightly greater than the original 35 deg. owing to the position imposed on the hone by the shape of the cutter block.

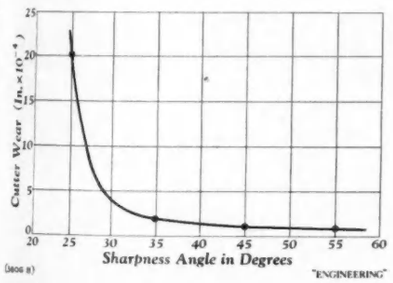


Fig. 1 Relation between cutter wear and cutter sharpness angle.

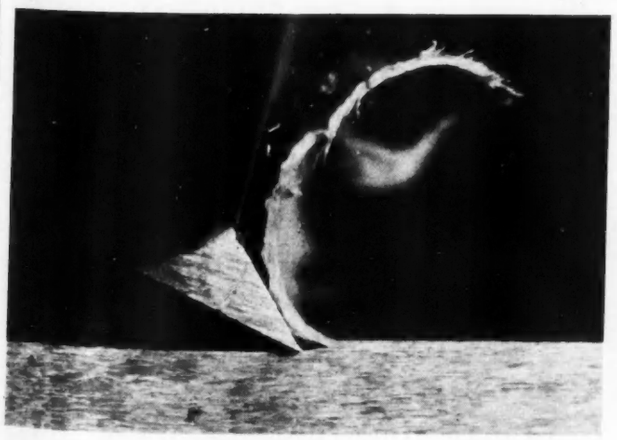


Fig. 2 High-speed photograph of chip formation during wood planing (× 6).

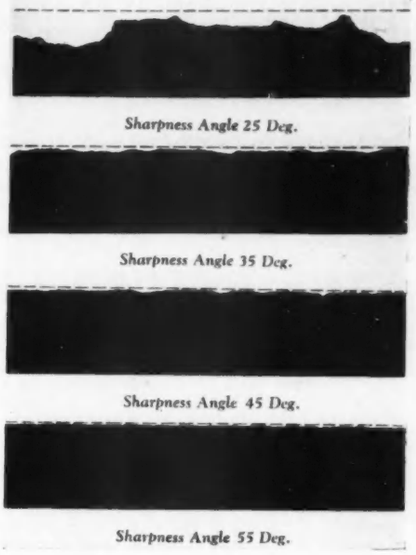


Fig. 3 Silhouettes (× 100) of edges after cutting 7,000 ft. of beech at 30 deg. cutting angle; original edge shown by broken line.

ADDITIONAL DATA ON NIMONIC 100

The latest creep-resisting alloy in the Nimonic series, Nimonic 100, is now in production for the rotor blades of a number of British gas turbines for aircraft, and additional data on this alloy, which has a useful load-carrying ability at temperatures approaching 1,000 deg. C., have been published by Henry Wiggin and Company, Limited, Wiggin-street, Birmingham, 16, who produce and market this series of alloys.

The specified percentage composition of Nimonic 100 is as follows: carbon (maximum) 0·30, titanium 1·0 to 2·0, chromium 10 to 12, aluminium 4·0 to 6·0, molybdenum 4·5 to 5·5, silicon (maximum) 0·5, iron (maximum) 2, cobalt 18 to 12, and nickel the balance. The hardness of solution-treated Nimonic 100 bar ranges from 280 to 360 diamond-pyramid numbers, and of fully heat-treated bar from 320 to 400 numbers. The alloy has a specific gravity of 8·04 and a melting range of 1,310 to 1,380 deg. C. At room temperature Nimonic 100 has a 0·1 per cent. proof stress of 53 tons per sq. in., a maximum stress of 81 tons per sq. in., an elongation of 18 per cent. on $4\sqrt{\text{area}}$, a reduction of area of 16 per cent., and a modulus of 31 × 10^6 lb. per sq. in.

The creep characteristics, after full heat treatment, are set out in Tables I and II below.

TABLE I

Temp.	Stress (tons per sq. in.) to produce a creep extension of :—					
	0·1 per cent. in—			0·2 per cent. in—		
	100 hrs.	300 hrs.	1,000 hrs.	100 hrs.	300 hrs.	1,000 hrs.
deg. C.						
815	13·4	10·6	(7·7)*	15·4	13·0	(10·0)
870	7·7	(5·4)		9·4	(7·0)	
940	3·2	(2·1)		4·0	3·1	(1·8)

TABLE II

Temp.	Stress (tons per sq. in.) to produce a creep extension of:—						
	0·5 per cent. in—			Rupture in—			
	100 hrs.	300 hrs.	1,000 hrs.	50 hrs.	100 hrs.	300 hrs.	1,000 hrs.
deg. C.							
750				27·0	24·9	21·7	(18·2)
815	17·2	14·6	12·0	19·2	17·4	14·6	11·5
870	10·4	7·9	(5·3)	13·7	12·4	10·3	8·1
940	4·8	3·8	2·7	8·1	7·1	5·4	3·5
980				5·2	4·2	2·8	1·3

* Extrapolated figures are shown in brackets.

The rotating bend fatigue properties of Nimonic 100 are as given in Table III.

TABLE III

Temp.	Stress range	Endurance
deg. C.	Tons per sq. in.	
750	0 ± 30·0	15 × 10^6 cycles in about 100 hours
815	0 ± 25·5	
870	0 ± 21·5	
940	0 ± 14·3	
750	0 ± 28·0	45 × 10^6 cycles in about 100 hours
815	0 ± 24·0	
870	0 ± 19·5	
940	0 ± 11·5	

Engineering Papers at the British Association Meeting

As in past years, we have made arrangements to publish all available papers that are presented to Section G (Engineering) of the British Association annual meeting. The presidential address by Mr. A. C. Hartley, C.B.E., on "Oil and Industry," was included in last week's issue of ENGINEERING. *The papers are as follows:—"Control flux wave form in the tracing of dynamics hysteresis loops"; "A review of boiling heat transfer with particular reference to unstable flow"; "Measurements of the velocity and deposit patterns of dust clouds"; "A simple method for automatic control of secondary air in combustion"; "Solid solutions in iron"; "High temperature alloys"; "Powder metallurgy"; "Improving cutting tool performance by practical research"; "The orthogonal cutting of a work-hardening material"; "The mechanics of the metal cutting process"; "General aspects of automation-Introduction, and The scientific background"; "Economic effects of automation"; "Problems and achievements in coal face mechanisation". Three of the papers are published on the following pages; others will appear in subsequent issues of* ENGINEERING.

THE NATURE OF A TRANSLATING MACHINE*

By Dr. Andrew D. Booth

During the last ten years, and arising out of a conversation between the author of the present paper and Dr. Warren Weaver,[1] the director for Natural Sciences at the Rockefeller Foundation, considerable thought has been given to the possibility of the automatic translation of one language into another.

In 1947 the ideas of translation were of a naïve type in which it was supposed that it would only be possible to use a machine as a sort of glorified mechanical dictionary. Experimental work on such machine uses was carried out at the Birkbeck College Computational Laboratory and elsewhere but it was not thought that this particular application of a calculating machine was one which would be likely to lead to a practical use.

Towards the end of the 1940's it became apparent that the great flexibility inherent in the control of a modern calculating machine should enable translations to be made, not only by the straightforward looking up of words in a dictionary, but also by the grammatical analysis of sentences and the recombination of words, after translation, into adequate representations in English or any other target language.

This work has now proceeded until at present it is not unfair to say that it is possible to translate adequately from French into English[2] and also, so far as can be judged from reports,[3] to translate from English into Russian. The methods used in these two experiments differ in detail but the results, as far as can be seen, are quite satisfactory. It will be the purpose of this paper, intended as it is for engineers, to discuss some of the requirements which must be met by a machine which is to translate; and this will mean that little attention will be paid to the linguistic analysis of languages, which is a prerequisite of any mechanical translation. It will be assumed, then, that structural linguistics as a science has already progressed to a state in which it is possible to devise adequate rules of procedure for translation from one language to another in terms which can be understood by a computing machine.

Calculating machines, as they exist at the moment, are designed essentially to deal with numbers. In many cases these numbers are represented in the binary scale and this is no disadvantage when translation is considered. The normal form of input of a message for translation is via a teletype tape and, as is well known, teletype apparatus automatically converts alphabetic symbols into five-hole code. This five-hole code is suitable for input directly to an automatic computer. Once the foreign language word has been transcribed into teletype code by means of the teletype keyboard one can regard the aggregate of coded impressions which go to make up a word as a binary number and the machine can then operate on such numbers in the normal way. The basis of any translation is a dictionary and for the purpose of machine translation it is necessary to restrict the dictionary to a size which can be contained in the storage organ of the machine. With machines which are at present available this restriction implies that the size of dictionaries stored can only be of the order of 1,000 words. It may be argued that a dictionary of such a size will be quite inadequate for general translation even from a single language, and this is quite true. At the start of the consideration of machine translation, however, this limitation was realised and it was shown by practical experiment that it would be possible to make adequate translation of something like 90 per cent. of words in most scientific passages by the simple expedient of having a dictionary divided into two parts. The first of these parts contains words which are of common usage such as "and," "if," "but," and so on. The second part contains a so-called micro-glossary which is a list of those words which are peculiar to the specialist subject of the paper or the document which is being translated.

* Paper read before Section G of the British Association at Sheffield, on Tuesday, September 4.

STEM ENDINGS

In the earliest experiments, the only words which could be recognised were those which exactly matched a word contained in the dictionary and it was therefore quite impossible to translate other than a microscopical proportion of the words in the text of an inflected language, that is, most languages other than English. The method of overcoming this, however, was not difficult to find. The idea of stems and endings must be familiar to anyone who has studied Latin, French or other European languages. From the machine point of view a new sort of dictionary was constructed; this consisted of stems of words, which can be defined for this purpose as the longest segment of a word common to all, or, at any rate, the greater proportion of its parts. For example, in the Latin word, *amo* the stem would be *am*, which could then take the endings, *o*, *as*, *bo*, *bis*, *bit*, and so on. Associated with the stem dictionary was to be a completely separate dictionary to contain the endings. The way in which words were to be handled was simple: having converted the foreign language word into a number by means of the teletype apparatus, this number was compared by subtraction with the numbers which represent stems in the dictionary stored in the machine. If an exact match was found, of course, the result of the subtraction at some point would become zero. In all cases, however, where an ending is present the result of the subtraction would be positive, whilst words which preceed the unknown word in the dictionary are being examined, and negative as soon as the foreign language word finds its match among the stems held in the dictionary.

This idea of discriminating by means of the positiveness or negativeness of the number is a commonplace in computer technology, so that the machines are ideal for operations of this sort. As soon as a negative result is obtained it is known that the word from which the foreign language word has just been subtracted is, in fact, the stem of that foreign language word. From this point various courses of action are possible. In the early experiments, having discovered the stem, the meaning of that stem was immediately typed at the output machine; for example, in taking the latin word *amat* there would be typed out *love*.

The next problem was to deal with the ending, and this was achieved by comparing the residue, after subtraction of the stem, with the contents of a completely separate dictionary. This dictionary gave, not translations of the endings, but some grammatical notes. For example, in the case of *amat* it gave a note to the effect that the word *love* was, in fact, third person singular present tense active mood. Translations which resulted from this sort of process were difficult to read and were, in many ways, unsatisfactory. The essential point, however, of the stem ending procedure is that whereas if (n) words are contained in the dictionary and each of these words can take (m) stems then the number of stem-ending combinations possible is ($n.m$) and each of these will have to be stored. On the other hand, by detaching endings, the storage requirements are reduced to ($n + m$) which, for values of (n) and (m) of any magnitude, is a considerable saving.

As the subject developed these early translations were considered less and less satisfactory and recently attention has been given to rendering texts into respectable prose. The means by which this is achieved is quite simple. Again the stem ending procedure is invoked but this time instead of the machine translating *amat* as say *love* it is this time output as *lov*. The machine, by examination of the Latin ending now finds, not a set of grammatical notes, but an appropriate ending which is to be added to the English stem which has already been typed at the output, in this way the word *amat* will be translated by *loves*.

A point which arises here is in fact the translation will probably be *he loves* or *she loves*, so that, in fact, the machine does not output *lov* at the early stage, but assembles the phrase *he loves* in its own temporary storage and then outputs the whole expression at a suitable time. This idea of hoarding up the actual typing of the translation until a later stage, is, of course, important when the more complicated problem of re-arranging sentence order in accord with a set of grammatical rules is considered, and the simple example just quoted will be sufficient to show that the machine is quite capable of doing this.

A further point which is worth mentioning here lies in the question of the resolution of ambiguities by the machine. It is possible for the word *noyau* in French to have the meanings *nut*, *kernel*, *centre*, or *nucleus* in English. Which of these meanings is the correct one will depend on the context; thus, in nuclear physics one might encounter the word *nucleus* in the experimental sense or, if the theory of the nucleus was being studied, one might encounter the word *kernel* in respect of an integral equation. On the other hand, if plant genetics was the subject under consideration the output might be *nut* or again *kernel*. Yet again, in a sociological context, the translation might be *centre*, or again *nucleus*.

The idea of a micro-glossary, which is specific to a given subject, removes most of the ambiguities. Those which still exist can be dealt with in two ways: either alternative meanings are typed by the machine, or it is possible for the machine to keep account of certain non-ambiguous words which give it a clue to the precise context of the passage to be translated. In this way the machine can select between the output meanings so as to produce a unique one. Although there is no technical difficulty in carrying out this operation it has not, so far as we know, been tried in any of the experiments so far done. At Birkbeck College it is not considered to be worth while because a passage, even though it contains a rather distant variant of the true meaning of the intended word, is usually still quite readable.

We next come to a detailed consideration of the attributes which a machine must possess if it is to translate. In the first place it must be capable of holding a dictionary. All modern computing machines[4] have an organ which is known as a "store"; this is often divided into two parts, a relatively small fast access store from which the actual calculations are performed, and a slower, far more extensive store which is used for holding data in large quantities. Such an organisation is ideally suited for translation. Unfortunately, the storage organs of present machines tend to be restricted to a size of between 1,000 and 8,000 words distributed between the high speed and the backing store. This is definitely too small to make possible an adequate translating machine.

The second attribute which a machine must have for translation is the possibility of performing the operation of stem ending separation. An example of this has been given earlier in this paper and it is clear that the only operations involved are those of subtraction and discrimination. These functions are already possessed by all existing machines so that no particular addition to the machine repertoire is required.

IDIOMATIC EXPRESSIONS

The next function which a machine must be capable of performing is the recognition of idiomatic expressions. The way in which this has been done is simple. An idiom is usually based on some keyword; it is arranged that all words which may form the basis of idioms are marked in the machine store in a suitable manner. In this way, whenever the

machine sees, for example, the French word *boîte*, it recognises that this word cannot be directly translated; it may mean *box*, but on the other hand, it may be the basis of the idiom *boîte de nuit*, which means *night-club*. Here again no machine function is required apart from the ability to discriminate.

The last linguistic function is that of the insertion of grammar and re-arrangement. This is a classical problem of data handling which can be treated by the ordinary processes of coding for an automatic computer. It need not detain us further.

AUTOMATIC DIGITAL COMPUTER AS A TRANSLATOR

It is now proposed to consider some results of practical experiments which have so far been carried out on machine translation, and to indicate how they suggest a design for the translating machine of the future. In the first place, as has already been indicated, the store of existing machines is far too small. This has restricted the dictionary which can be inserted into present day machines to between 250 words and 1,000 words. Since no attempt has been made to do commercially useful translation on a machine, the restriction has, up to the present, been quite unimportant. It must, nevertheless, be borne in mind in considering a future design.

In the second place one has to consider the arithmetical unit of the machine. It has already been mentioned that the only arithmetic operation which is required in translation is that of subtraction. For various purposes it is often useful to be able to add and also to be able to shift words or numbers about in the machine itself. Shifting, addition and subtraction are operations which are relatively simple to engineer. The important thing is that a translating machine does not need to have a multiplying unit. Apart from reference to and from the store the only other operation the machine must be capable of performing is that of discrimination, and this all existing machines are built to do.

The next point to be considered is the detailed question of how the dictionary is searched. It was mentioned earlier that the search procedure involved the subtraction of the foreign language word from successive entries in the dictionary. The dictionary entries are, of course, arranged in ascending order of numerical magnitude so that the result of the subtraction will be negative until the stem translation is reached, and after this point will become positive. It is clear that if we choose a word at random, on the average it will be necessary to examine half of the dictionary words before the translation is found. This is highly undesirable and a vastly improved technique has been worked out. In this, the foreign language word is first subtracted from a word which is roughly half way between start and finish of the dictionary. If the result of this subtraction is positive then it is clear that the word to be translated lies in the first half of the dictionary. If, on the other hand, the result is negative, then the word is known to lie in the second half of the dictionary. The process is now repeated using this time a word which is either one quarter of the way through the dictionary, or three-quarters of the way, and thus it will be found that the foreign word lies in a particular quarter of the dictionary. Repetitions of the process will limit the possible position of the translation to one eighth, one sixteenth or so on of the possible dictionary words, and it is quite easy to show that for a dictionary containing n entries the number of look-ups is approximately $\log_2 n$. This is an enormous improvement over the previous method of comparison with successive dictionary words. For example, if a dictionary of the size of the Concise Oxford Dictionary is considered it is easy to show that it would be necessary to look at approximately 50,000 words if the sequential mode of scanning is adopted. On the other hand, by the partitioning method the number of trials is reduced to about 14 or 15. The effect of this is that any modern computing machine could scan a dictionary of, let us say, one million words in a time of well under 1 second, and this is amply adequate for any of the needs which are at present envisaged.

The next point to be considered is that of storing the actual dictionary itself. It has already been mentioned that the store is too small in numbers of words; it is also true that computer words are of insufficient length. If sections of text are examined it will be found that the words in many foreign languages have an average length of about ten letters; there is, however, a considerable spread, and words of 20 letters are not uncommon; neither, of course, are words of one letter. The storage of such words in the machine tends to be uneconomical; for programming reasons it is highly desirable that all "real language" words should occupy the same number of computer words, and to accommodate words of up to 20 letters four computer words are needed. It is by no means impossible to arrange that small words are packed, say four words into one computer word, larger words two into a word and so on, but this leads to complexities of programming. The effect of this is to suggest that probably the modern ideas on word length for digital computation are not suitable for a machine whose primary purpose is translation.

Finally, we give below an example of machine translation. This we feel will need no comment; its strength and defects are immediately obvious.

L'étude des fonctions définies par une équation différentielle, dans tout leur domaine d'existence, est un problème, dont la solution complète, dans le cas général, dépasse actuellement la puissance de l'analyse. On a cependant obtenu des résultats du plus haut interêt en se limitant à l'étude des intégrales infiniment voisines d'une intégrale connue. C'est ainsi que, dans ses mémorables travaux sur le "Probleme des trois corps," H. Poincaré a pu démontrer l'existence d'une infinite de solutions périodiques et de solutions asymptotiques à une solution périodique.

The study of functions defined by a differential equation, in all their sphere of existence, is a problem of which the complete solution, in the general case, surpasses actually the power of analysis. One has nevertheless obtained results of highest interest while limiting oneself to the study of infinitely adjacent integrals of a known integral. It is just so that, in his memorable works on the "Problem of three bodies," H. Poincaré has been able to demonstrate the existence of an infinity of periodic solutions and of asymptotic solutions to a periodic solution.

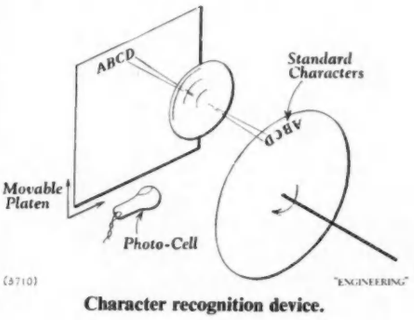
PROBLEM OF INPUT-OUTPUT

It is, of course, necessary to be able to insert data into a computing machine, or any machine which is to translate, and it has already been mentioned that this is at present effected by means of a teletype apparatus. On the other hand it cannot for a moment be supposed that this is an efficient means of input. This is because it implies that any document which is presented to the machine must be re-typed before the machine can deal with it. Such a re-typing is to say the least, costly and may, in the case of translations from languages which do not employ a Roman script, be extremely difficult. This leads naturally to the idea that an ideal translating machine would have, as a part of its equipment, some means of reading directly from an original document.

Three major methods may be mentioned. The first makes use of a set of masks upon which are cut representations of the characters to be recognised. By means of an optical system a bright image of the characters is projected on to the unknown character. Only when the bright image and the unknown character coincide completely is a minimum of illumination obtained, and this can be used to indicate to a machine the nature of the character on the original document. A diagrammatic version of such a recognising device is shown in the accompanying figure.

The second class of character recognising device is based upon a logical analysis of character shape and this is normally conducted by means of a scanning pattern whose intersections with the character lead to a set of discriminations which enable the character to be recognised. A large experiment based on these principles has been carried out by the I.B.M. Corporation in the United States.[5]

The third method, which is one which has been tried at Birkbeck College, scans the unknown character by means of the projected image obtained from the flying-spot projection tube. The times of intersection of each line of the scan pattern with the unknown character ($u_{it}\ i = 1\ ..\ n$) are obtained and are fed to the computer itself. If the computer has previously had stored in it the sets of sampling numbers ($s_{itj}\ i = 1\ ..\ n,\ j = 1\ ..\ m$) which have been obtained from the characters to be recognised, it is evident that when $\delta_j = \sum_{it} | u_{it} - s_{itj} |$ is a minimum



Character recognition device.

with respect to j then it is probable that the unknown character corresponds to the standard character (j) giving rise to the sampling numbers (s_{itj}). On the other hand it may happen that several characters from the standard set give minima of (δ_j) with the unknown character. In this case the machine alters the scanning pattern and produces a second set of sampling numbers from the unknown character. The scanning raster may, for example, be taken at right angles to the first one. The comparison process is again performed and the results this time will probably show other ambiguities, but only for the exact match will it happen that there is a common minimum between the first set of observations and the second. The method may be extended, in the event of imperfect recognition being obtained, to the use of still further scan patterns, say diagonal or spiral ones. The work so far carried out at Birkbeck College has been directed only at the recognition of the digits 0 to 9 and it turns out that for these it is very rare to have to proceed further than the first vertical scanning pattern.

The importance of character recognition as an input to a translating machine is that it would enable languages such as Russian, Chinese, Japanese, Arabic, Greek to be input to the machine, whereas without such recognition devices specially trained typists would have to be employed.

A further aspect of input mechanism is that of speech input. A certain amount of work has been carried out in this branch of the art, pioneered by the Bell Laboratories of the U.S.A. Speech recognition systems at present available do not appear to be capable of great reliability. A variant which was tried at Birkbeck College[6] makes use of a similar sampling technique to that mentioned in connection with recognition of printed characters. Effectively, spoken sound is applied to a microphone, amplified, and turned into a voltage wave form. This voltage wave form is then passed into three channels: in the first as an unmodified wave form, in the second through a low pass filter, and in the third through a high pass filter. The outputs from these three channels are now standardised as far as amplitude is concerned, and the number of axis crossings in a given interval of time is measured by means of standard binary counters. The three numbers thus obtained are fed into a computer and recognition is achieved by comparing the numbers thus obtained with numbers previously obtained in a standard experiment. The results of this work suggest that if care is taken to standardise the duration of each word, and if the computer works from a record made by the person who is to use the apparatus, then for the digits 0 to 9 it is possible to obtain a considerable perfection in recognition.

The more general proposition of recognising words is far more difficult and although some progress has been made along these lines, notably at University College by Fry and Denesh,[7] it cannot be said that at present there is much hope of applying this sort of technique to machine translation.

Last, but not least, it is necessary for a translation machine to produce an output. The outputs at present available are usually either punched teletype tape, or direct imprint on a teletypwriter or other form of electrical typing device. The speeds thus obtainable are of the order of seven letters per second for direct typing, or 25 letters per second if a punched tape is used, but there is no reason why these speeds cannot be greatly improved by the use of one of the parallel printing devices which are at present available.

It is not beyond the realms of possibility that, in the somewhat distant future, a machine output may be produced in the form of a spoken record, and in this way the science fiction author's dream of an electronic translating machine from speech to speech may be realised.

PRESENT ECONOMICS OF MACHINE TRANSLATION

Machine translation at the present time is limited by the inadequate store which is possessed by existing machines. This means either that very restricted micro-glossaries have to be used or, alternatively, that translation cannot be made without some intermediate form of input such as a punched paper or magnetic tape. Both of the latter forms of input for dictionaries are extremely slow. With this restriction, however, the speed which can be obtained by present day machines in translating French is of the order of 1,000 to 3,000 words per hour, depending entirely upon the complexity of the grammatical analysis which is required. The implications of this so far as any practical use of a translating machine is concerned are interesting. The cost of time on a computing machine is of the order of £30 per hour; a human translator can translate about 1,000 words of text into very presentable English in this period and his remuneration would be unlikely to exceed 10*s.* to £1, so that it is clear that at the present time

the machine is uneconomical by a factor of at least 30. This does not mean, however, that work on translation by computing machines is worthless; this is by no means the case. Many machines are coming into operation at the present time and programmes once prepared for a given machine are easily transformed into a suitable form for any of the other machines. Machines frequently have small amounts of time available and this, because it would not normally be accountable, could be used for translating papers for the scientific staff of the machine laboratories.

A further great advantage occurs when exotic languages have to be translated. It would be possible for a machine to deal with such things as Russian, Chinese, Albanian, Arabic, Japanese and Hindustani whereas it is very unlikely that any given laboratory would have personnel available to deal with such languages.

TRANSLATING MACHINE OF THE FUTURE

To conclude this account of machine translation it is worth setting forth some of the characteristics of a translating machine which may be constructed sometime within the next five or ten years. Prediction is always risky but since our subject is now a decade old at least some trends of the machine can be seen with fair accuracy.

First as to storage: it seems extremely likely that magnetic drum storage (or some better system which may be developed) will be ideal for the major storage unit of the future translating machine. Its capacity should be between 20,000 and 60,000 words. There is no impossibility in constructing stores of this size at the present time; given the funds, it would appear likely that the cost of a 60,000 word store should not exceed £2,000 to £3,000.

Associated with the idea of storage is that of word length. Computing machines, at present, deal with numbers whose length is about 10 decimal digits, or, let us say, 30 to 40 binary digits. The ideal translating machine would, we think, have a word length which approximates to 250 binary digits. With a word of such a length it would be possible to store alternative translations, and grammatical notes in a single word, and the difficulties of recognising words of considerable length from given languages would be removed. An attractive possibility is that the machine might operate with words of variable length. A number of designs for this type of machine have already been proposed and a great saving in storage space will be attained by this incorporation in any translator.

The arithmetic operations which the machine could perform will simply be those of addition, subtraction, shift and conditional transfer so that structurally the machine would be of great simplicity.

The input to the machine will probably be in the form of a device for the recognition of printed characters; it might, alternatively, be a device which could recognise speech directly. The output of a machine constructed in the next decade would most probably be a parallel printer capable of an output speed of the order of 1,000 lines of type per minute.

Finally, as to speed. Using existing techniques it would be quite simple to construct a machine having all the required characteristics except those apertaining to character recognition and spoken word input and output and whose speed would be one word per second. In the future it seems probable that this speed might be increased by a factor of 10. The effective cost of translation would thereby be reduced to about £3 per hour, and when the great advantages attendant upon a completly mechanised translation is considered this would seem to be completely worth while.

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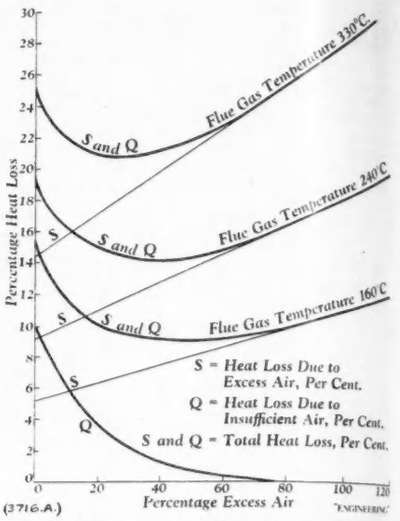
Flue Gas Temperature 330°C
S and Q
Flue Gas Temperature 240°C
S and Q
Flue Gas Temperature 160°C
S and Q
S = Heat Loss Due to Excess Air, Per Cent.
Q = Heat Loss Due to Insufficient Air, Per Cent.
S and Q = Total Heat Loss, Per Cent.
Percentage Heat Loss
Percentage Excess Air
(3716.A.)
"ENGINEERING"

Fig. 1 Heat losses in chain-grate stoked boiler.

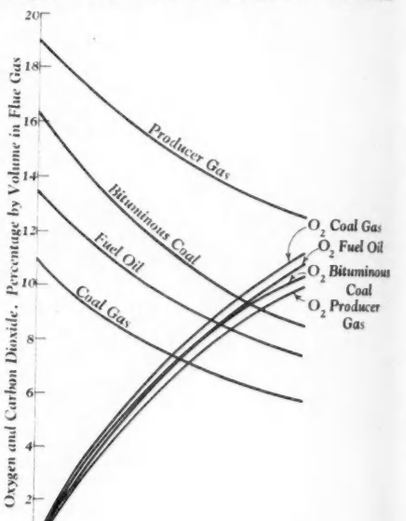

Fig. 2 Relationship between oxygen, carbon dioxide and excess air.

AUTOMATIC CONTROL OF SECONDARY AIR IN COMBUSTION*

AN OXYGEN CONCENTRATION METER

By M. G. Perry, B.SC.(ENG.) (RAND)

An experimental apparatus for measuring the oxygen concentration of flue gases has been constructed and tested in the laboratory. The meter is activated by the variation in the heat released from a pilot flame burning (with a large deficiency of primary air) in a surrounding atmosphere of varying oxygen concentration. The heat released activates a metallic differential expansion system. The use of the apparatus as a primary measuring element in an automatic control system for the secondary air of a combustion appliance is discussed.

The use of indicating and controlling instruments for combustion regulation is widely accepted on large-scale installations as contributing to their efficient operation. On the other hand with small installations, comprising only one or two units, the tendency is to dispense with all indicators not required by law or the insurance companies. The fireman is then relied upon to operate the unit so as to satisfy the demands made on it and to steer clear of the smoke inspectors. He cannot do either with the maximum fuel efficiency without an indication and hence control of combustion conditions.

It is not, in general, practicable to operate commercial plant with the theoretical quantity of air, especially when a solid fuel is being burnt. Every furnace is designed to operate at maximum efficiency with a given fuel and a corresponding proportion of air, which may range from 110 to 180 per cent. of that theoretically required. Operation of the furnace with a quantity of air above or below that for which it was designed entails a loss in efficiency and a waste of fuel. Fig. 1 shows the magnitude of the heat losses incurred in firing a boiler fitted with a chain-grate stoker with various proportions of air. It is evident that unless the amount of air supplied is controlled, the heat losses are unnecessarily high. In the case of small hand-fired furnaces control of the secondary air is most important if smoke emission and heavy heat losses are to be avoided.

The initial cost of indicating instruments to assist proper combustion control is a reason frequently advanced against their use on small units. Often, where they are installed, their use is imperfectly understood and they can then rightly be regarded as wasted expenditure. There is therefore a need for a simple method of indicating and preferably of automatically controlling combustion conditions to obtain the maximum efficiency and to save fuel.

An indication of combustion conditions in a furnace may be obtained by measuring the CO_2 or O_2 content of the flue gases. A measurement of the CO_2 content is at present the more common method. It is only really satisfactory, however, when the fuel properties and grading remain consistent since changes in these can give rise to changes of one or two per cent. in the CO_2 content of the flue gases for a given percentage of excess air. Again, if different types of fuel are burnt in the same furnace at various times, quite different CO_2 contents result for a fixed percentage of excess air, while the changes in the oxygen content are much less marked, see Fig. 2. In some cases CO_2 is given off by materials being treated in a furnace and is carried away in the flue gases. For these reasons it is preferable to measure the O_2 content of the flue gases, and to base combustion control on this figure.

The air for combustion in a furnace is usually introduced in two stages as primary and secondary air, the secondary air being introduced subsequently to the primary, that is over the top of the fuel bed in many boiler furnaces, the primary air entering below the fuel bed and passing through it. The amount of excess air can then normally be regulated by coarse setting of the primary air and fine control of the secondary air. To attempt to meet the need for a simple method of indicating and controlling combustion in small units an experimental apparatus to measure the O_2 content of flue gases has been constructed and tested in the laboratory. It depends for its operation on the heat released from a small flame of town's gas and air burning in a surrounding atmosphere composed of the flue gases of which the oxygen content is required. The heat released activates a metallic differential expansion system.* It was suggested that a simple mechanical linkage between a damper on the secondary air supply and the expansion system would provide automatic control. The experiments thus had two purposes: firstly to establish the suitability of the apparatus as a primary measuring and indicating means for the oxygen content of flue gases and secondly, in the light of the experimental results, to assess its use in an automatic control system for the secondary air.

EXPERIMENTAL APPARATUS

The apparatus and experimental flow circuits are shown in outline in Fig. 3, Fig. 4 giving a general view of the layout. The expansion system is formed by two concentric tubes, the outer tube resting in a recess in a rigid Syndanyo platform. The inner tube passes through the Syndanyo sheet and projects slightly below it, being held in position with a metal bush. The outer tube of aluminium is 2½ in. o.d.,

* Paper read before Section G of the British Association at Sheffield on Thursday, August 30.

* British Patent Application No. 14731, 1954.

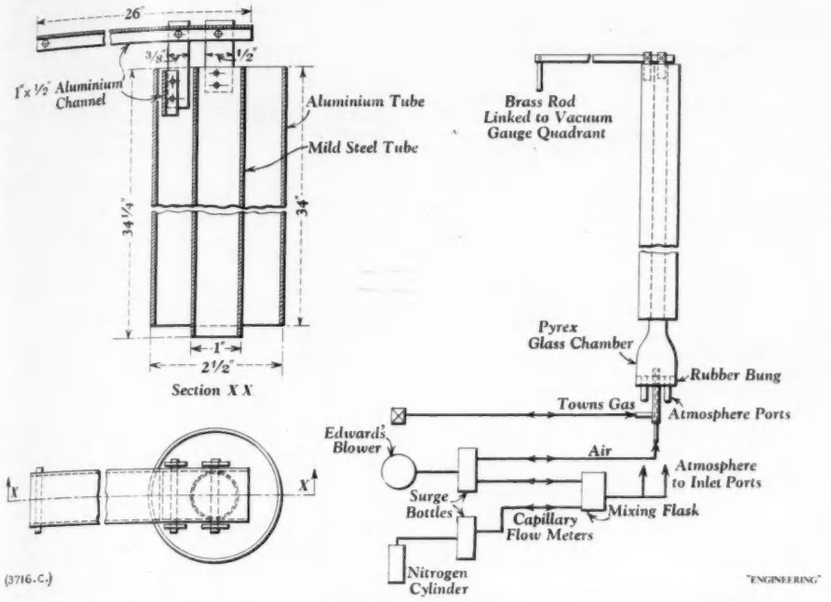

Fig. 3 Showing (left) details of expansion system and lever arm, and (right) schematic diagram of experimental layout.

and the inner tube is 1 in. o.d. of thin walled mild steel. The Syndanyo sheet is perforated in the annulus between the two tubes to allow a circulation of air to keep the outer aluminium tube as cool as possible. The aluminium tube is braced near its upper end by a second piece of Syndanyo sheet, through which it passes. The supporting structure is built up of Dexion angle. A 2 ft. 2 in. length of 1 in. × $\frac{1}{8}$ in. aluminium channel is carried on pivots between metal strips fixed to the two tubes so that the differential expansion between the two tubes causes a movement of the distant end of the channel. This movement can be measured, as in these experiments, or used to link up with a damper control system for the secondary air of a combustion appliance.

Fixed below the expansion system is a Pyrex glass combustion chamber which fits over a large rubber bung in which the burner and atmosphere ports are mounted, as shown in Fig. 5. The combustion chamber is narrowed at the top and fits over the chamfered end of the inner steel tube just meeting the steel bush holding the tube in the Syndanyo sheet. The joint is made gas tight with a refractory cement. The atmosphere ports consist of $\frac{5}{16}$ in. i.d. brass tubing and are fixed so that one end is flush with the bung surface, which is protected by a thin layer of refractory cement, while the burner projects $\frac{1}{2}$ in. above the surface in the centre of the bung. The four atmosphere ports are arranged in a circle round the burner. In some initial experiments using the two atmosphere ports diametrically opposite, it was found that the oxygen content of the atmosphere had to be as high as 14 per cent. by volume before any combustion of the excess gas from the pilot flame occurred. At this point almost complete combustion of the excess gas took place. Since it was necessary to be able to detect and measure very much lower oxygen concentrations, the system as it stood was obviously unsatisfactory. It seemed evident that, when the atmosphere contained less than 14 per cent. of oxygen, flow conditions in the burner chamber were such that mixing between the gases from the pilot flame and the atmosphere flow occurred so slowly that the flame gases were cooled by radiation below the ignition temperature before adequate mixing could take place. Flow-breakers of thin brass sheet were therefore fitted into the atmosphere ports and arranged so as to induce mixing of the various gas streams close to the pilot flame in the burner. With this arrangement very low oxygen concentrations in the atmosphere could be detected. The burner consists of two concentric tubes, $\frac{5}{32}$ in. i.d. and $\frac{9}{32}$ in. i.d. respectively, which gave approximately equal areas for the annulus and inner circle so that at equal rates of flow the velocities of the air and gas streams were nearly equal. Fig. 5 shows the bung with the burner and atmosphere ports.

In operation the displacements of the end of the aluminium channel, which correspond to the various oxygen concentrations of the atmosphere passing through the burner chamber, were measured in two ways. Small displacements were observed by linking a brass rod, pivoted at the end of the channel arm, to the quadrant of a disused vacuum gauge. Larger displacements were measured by attaching a small pointer to the brass rod which moved over a scale cut into a piece of aluminium channel.

The rates of flow of the various gas streams were measured using glass capillaries and manometer tubes. The capillaries were calibrated with a wet gas meter. To provide an atmosphere of varying oxygen content, simulating a flue gas, air and nitrogen were mixed in the required proportion and passed into the combustion chamber through two of the atmosphere ports. The air supply was obtained from an Edwards' blower and the nitrogen from a cylinder. Surge bottles were placed in the flow circuits to prevent fluctuations in the flows.

EXPERIMENTAL TESTS

It was first necessary to investigate the range of flow rates for which the pilot flame was stable since it must continue to burn at all times. It is maintained by supplying an equal quantity of town's gas and air to the burner, the amount of air being about 25 per cent. of that necessary to burn all the gas. The gas and air burn as a diffusion flame, the gas flowing up the annulus between the two concentric burner tubes and the air through the inner tube. The gases from the burner chamber pass through the inner tube of the expansion system, their temperature varying as the amount of gas burnt and hence as the O_2 content of the atmosphere. The stability of the pilot flame depends on the gas and air rates and on the atmosphere flow rate when the atmosphere has zero oxygen concentration. The flow rate of the atmosphere, consisting of N_2 only, was kept constant in turn at values from 0·1 to 0·7 cub. ft. per minute, while the air and gas flows were varied over the range 0·01 to 0·045 cub. ft. per minute. These experiments showed that a stable flame could be obtained with air and gas flows between 0·01 and 0·04 cub. ft. per minute, provided that the atmosphere flow was below 0·5 cub. ft. per minute. With atmosphere flows above this value all the flames investigated became progressively unstable.

The characteristics of the apparatus as a primary measuring element for oxygen concentration were then investigated. The experiments were carried out by randomising selected flow settings for the air and nitrogen forming the atmosphere, to give oxygen concentrations by volume in the range zero to 5 per cent. and zero to 21 per cent. The gas and air flows to the burner were fixed and readings of the displacements of the aluminium channel were made as the oxygen concentration of the atmosphere varied.

With gas and air flows to the burner of 0·03 cub. ft. per minute and an atmosphere flow of 0·3 cub. ft. per minute, the movements of the aluminium channel were observed when the oxygen content of the atmosphere varied between zero and 5 per cent. by volume. The measurements were made using the vacuum gauge quadrant and pointer. At each change in the oxygen content of the atmosphere readings were made of the rate of change of the meter displacement until a steady reading had been reached. The results are shown graphically in Fig. 6.

Reducing the gas and air flows by half (and the

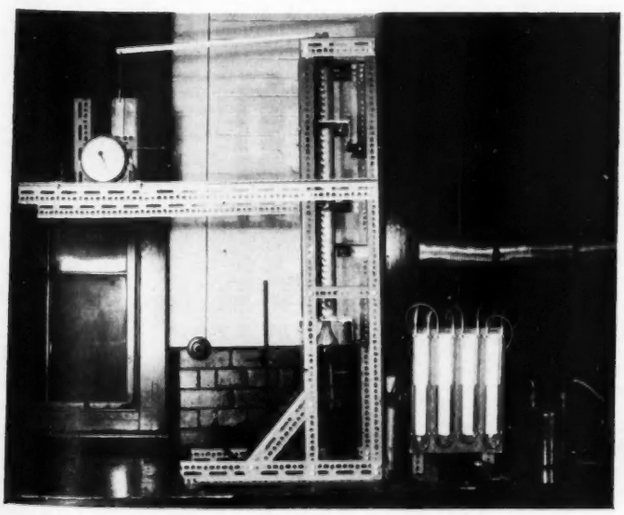

Fig. 4 (left) Arrangement of experimental apparatus for measuring oxygen concentration. Differential expansion of two tubes moves the lever which in turn operates the indicator.

Fig. 5 (right) Burner chamber, showing burner and atmosphere ports with "flow-breakers."

atmosphere flow to 0·15 cub. ft. per minute), and varying the oxygen content of the atmosphere between zero and 21 per cent. gave the movements shown in Fig. 7. These were measured by the pointer moving over the scale marked on the aluminium channel. Fig. 8 gives the displacements obtained when the gas and air flows are set at 0·015 cub. ft. per minute with an atmosphere flow of 0·3 cub. ft. per minute, the oxygen content of which varies from zero to 21 per cent.

Figs. 6, 7 and 8 show that the apparatus can be adjusted to respond to variations in the oxygen content of the atmosphere. The nature and extent of the response depend on the oxygen concentration of the atmosphere and the flow settings to the burner chamber. In the series of tests represented in Fig. 6, where the oxygen concentration varies between zero and 5 per cent., the displacements are small but reproducible and the scale readings are in direct proportion to the oxygen concentration. This occurs since the quantity of oxygen being supplied in the atmosphere is always well below that required to burn all the excess gas from the burner, so that the heat released is relatively small. In the experiments represented in Figs. 7 and 8 a marked response is obtained to oxygen concentrations in the ranges 5·5 to 10 per cent. and 3 to 7 per cent. The maximum displacement is reached in Fig. 7, with an oxygen

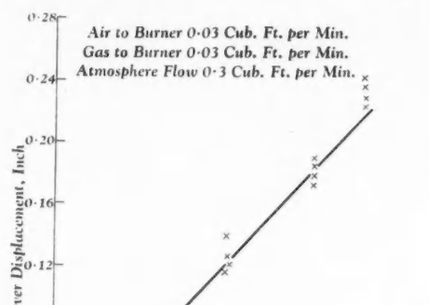

Fig. 6 High air and gas flow with high atmosphere flow.

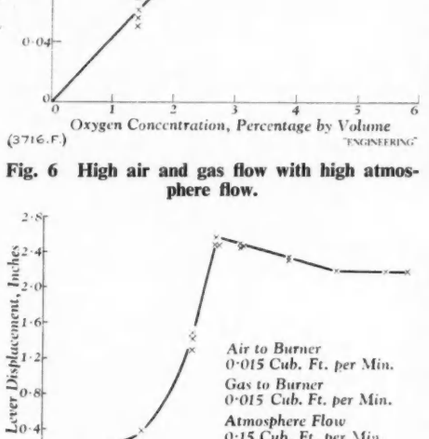

Fig. 7 Low air and gas flow with low atmosphere flow.

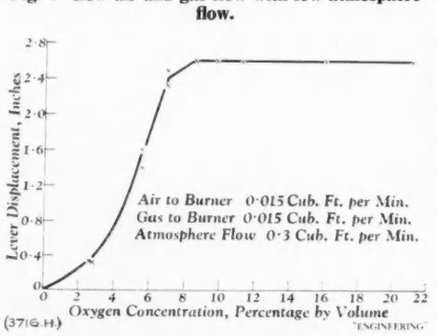

Fig. 8 Low air and gas flow with high atmosphere flow.

concentration of 10 per cent., and in Fig. 8 with an oxygen concentration of 8 per cent. At higher oxygen concentrations the displacement falls or rises slightly and then remains constant. With the fixed flow rates, the stoichiometric amount of oxygen is being supplied when the oxygen content of the atmosphere is 7·5 per cent. or greater for Fig. 7, and 4·3 per cent. or greater for Fig. 8. Due to mixing conditions in the burner chamber, nearly complete combustion of the excess gas from the pilot flame, giving the maximum displacement, only occurs when the atmosphere contains in one case 10 per cent. and the other 8 per cent. of oxygen. Thus by adjusting the various flows to suitable values the apparatus can be set to respond over a given range of oxygen concentrations.

In all the experiments the reproducibility was good and the apparatus sensitive to changes in the oxygen concentration of a maximum of 0·5 per cent. The apparatus responded rapidly to changes in the oxygen concentration, but took some eight minutes to come to a steady reading. In all cases, however, some 80 per cent. of the total movement occurred within three minutes.

APPLICATION TO AUTOMATIC CONTROL

For a primary measuring means in an automatic-control system three factors are important: the reproducibility, the sensitivity and the nature and speed of response to changes in the controlled variable. The experiments showed that the apparatus is suitable as a primary measuring means for oxygen concentration.

It had been hoped that a simple mechanical linkage to the expansion element would suffice to adapt the apparatus to an automatic control system for the secondary air on a combustion appliance. However, examination of Figs. 6, 7 and 8 shows that in those cases (Figs. 7 and 8) where the movement of the expansion element is sufficient to activate a mechanical linkage, the controller mode would be closely approximating a two-position mode of control. This would be unacceptable for combustion control since the controller would hunt and the controlled variable, the oxygen concentration of the flue gases, would cycle excessively. It would be necessary, therefore, to use a pneumatic proportional control system with the apparatus as the primary measuring element. The apparatus would then be adjusted so that the controller scale is linear; for example, over the range zero to 5 per cent. oxygen, flow settings as in Fig. 6 would be satisfactory. Some offset would result depending on the rate at which the furnace was being fired. This would not necessarily be objectionable in combustion control, but if very close control were desired a proportional reset response control system would have to be installed.

Conclusions.—(1) The suitability of the apparatus as a primary measuring means for oxygen concentration has been demonstrated. (2) For automatic control of the secondary air in combustion appliances it would be necessary to use a proportional control system with the apparatus as the primary measuring means.

Acknowledgements.—The author thanks Professor M. W. Thring for his advice and encouragement in this work; the work of Mr. A. Baxter and Mr. G. S. Hanson on some aspects of the problem has also been of value.

ATOMIC ENERGY AND AUTOMATION*

USE IN SAMPLING AND CONTROL

By Denis Taylor, M.SC., PH.D., M.I.E.E., F.INST.P.†

Automation has a large part to play in the development of atomic energy. The application arises in two different forms in this case. Firstly, there are those processes which occur in any industry that can be carried out manually, but which by the introduction of automatic machinery can be carried out on the large scale more satisfactorily. Secondly, there are those processes, peculiar to atomic energy, which because of radiation hazards are difficult or impossible to carry out manually and can only be carried out satisfactorily on a large scale by the introduction of automatic methods. I shall hope to deal with examples from both categories in the following.

AUTOMATION AND LABORATORY PROCESSES

Most laboratories concerned with atomic energy become involved in a great deal of routine radioactive assay. The number of samples to be assayed per day varies, of course, according to the nature of the work, but much of it can be exceedingly laborious as it may involve counting the radioactive emissions over a long period of time (up to several hours in some cases) to obtain the required statistical accuracy of measurement. This is a process which can be made automatic, and it is now normal practice, in all the larger laboratories at least, to install automatic radioactive assay apparatus for this routine work.

The form the apparatus takes depends very much on the precise method of measurement required, but the apparatus shown in Fig. 1 is typical of many installations and is in use on a large scale in the U.K.A.E.A. establishments. It comprises a sample-changing mechanism which takes the samples to be assayed one tray at a time and inserts them in turn under a radiation detector (usually a Geiger counter or a scintillation counter), and removes the sample at the other side at the termination of the measurement. The detector with the associated electronic apparatus measures the number of radioactive emissions in a certain time, records the results and computes the disintegration rate (proportional to the counting rate) which is a measure of the quantity of radioactive material present in the sample; this also is recorded. Machines of this sort are capable of working night and day with practically no attention and very soon pay for themselves.

One of the special problems which arises with this type of apparatus is the form to be taken by the controller. If time-controlled operation is employed each sample will be counted for a certain pre-set time. This may be convenient if all samples are of approximately the same strength, because then all measurements will be made to approximately the same statistical accuracy. However, if the samples are of widely varying activities the precision of measurement will vary widely from sample to sample. A more satisfactory method might be to use count-controlled operation instead of time-controlled operation. All measurements will then be made to the same statistical accuracy, but weak samples may be assayed for an unduly long time. A still more satisfactory method is to terminate the measuring period by a summation number determined by the sum of the counting pulses (from the detector) and the timing impulses (from a standard clock mechanism). If n is the total number of counts plus time impulses and t is the total number of time impulses during a measurement, then the counting rate is $\frac{(n-t)}{t} = \frac{n}{1-t}$

When the counting rate is high, the number n comprises a large number of count pulses from the detector and a small number of time impulses. This means that frequent recordings of the counting rate are made. When the counting rate is low, n is mainly comprised of time impulses and recordings are made infrequently. By a suitable choice of the number n and the frequency of the timing impulses it is possible to achieve a reasonable statistical accuracy for the higher counting rates (active samples) without wasting time unnecessarily on the lower counting rates (weak samples). This is illustrated in Table I. Here the timing impulses occur every 1 second and $n = 10^3$.

Another example of automation in the laboratory is the apparatus which we now use for rare earth separation in fission product analysis. An ion exchange column is used and the eluate is collected in collecting bottles, a different bottle being used for each fraction. The mechanism is shown in Fig. 2 and uses 50 collecting vessels on a turntable which is raised automatically to the capillary end of the ion exchange column. When the fraction has been collected, the turntable is lowered automatically and this causes a novel escapement mechanism to rotate

TABLE I

Timing impulses	Count pulses	Counting rate (counts per sec.)	Standard deviation, (per cent.)
10	9,990	999 ± 9·994	1·000
100	9,900	99 ± 0·995	1·005
500	9,500	19 ± 0·1958	1·025
1,000	9,000	9 ± 0·0948	1·034
5,000	5,000	1 ± 0·014	1·41

* Summary of paper read before Section G of the British Association at Sheffield on Tuesday, September 4, 1956.

† U.K.A.E.A., Atomic Energy Research Establishment, Harwell.

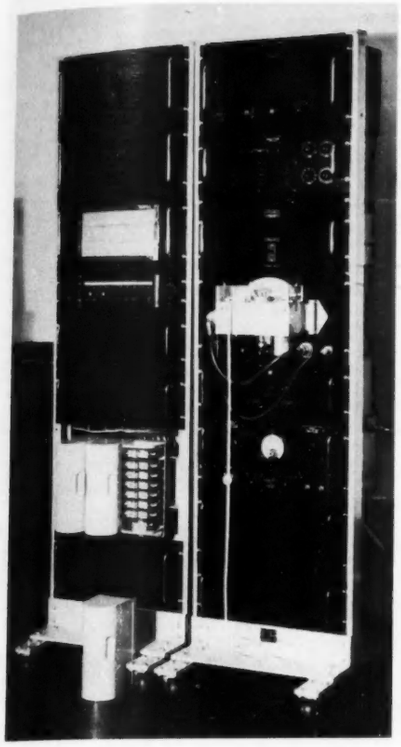

Fig. 1 To perform routine assays of radioactive samples, an apparatus has been developed to assay and record a series on a statistical basis.

the turntable and bring the next vessel under the capillary tube. The counting rate, as determined by a Geiger counter near the capillary, is plotted by a recording meter for later identification of the fractions, the vessels being changed automatically each time this rate goes through a pre-set level.

DATA PROCESSING IN EXPERIMENTAL WORK

Automation finds many applications in the atomic energy field in the processing of experimental data. A good example is the study of cosmic ray showers, and a common experiment is the observation of the coincidence rate of two counters as a function of their separation. The experiment may be extended to include the coincidence rate of three or more counters as a function of the size of the geometrical configuration, triangle, square, etc. In a particular experiment 16 counters were arranged in a square lattice giving triangles and squares of five sizes and rectangles of four sizes. At each coincidence of three or more counters the locations of those which were triggered is recorded photographically. The relative coincidence rate of the 14 configurations can then be obtained by examining the film. To aid in the analysis a unit was designed with 16 switches, so that each configuration could be set in manually and the apparatus then recognises and clocks up automatically the various configurations on registers. In other cases[1] the information is stored on a tape and sorted electro-mechanically instead of visually into groups, corresponding to the discharge of various arrangements of counters.

Punched cards are being increasingly used as a medium for recording information and the U.K.A.E.A. now possesses a great deal of machinery for analysing and printing out information recorded on punched cards. There are thus advantages in recording experimental data in this way. To enable this to be done a unit[2] has been devised recently which allows a standard card punch to be linked with devices which can provide information in digital form. As an example of its application the method is being used to record information stored on a 100 channel pulse amplitude analyser (as used for plotting energy spectra in radiochemical analysis), where up to 19 binary digits are extracted from each of the 100 channels and recorded in octal form. The 900 octal digits, together with suitable codes for card identification are punched on to 10 cards in 67 seconds, and so a record can be made very quickly of any results for which the full detail is required. These units are proving very useful.

PROCESS INSTRUMENTATION

One of the significant developments during post-war years in chemical plants with industrial scale production has been the changeover from batch processing to continuous-flow techniques. This has also been the case in the atomic energy field. Automatic control for plants processing radioactive materials on an industrial scale are a particularly attractive proposition because of health hazard questions. However, for the present, developments in the U.K.A.E.A. are short of this, although in an earlier paper[3] it was noted that the "monitor for record" stage is developing into "monitor for control" and even "monitor for automatic control" in some cases and this is still true.

Many examples can be cited here. A particularly interesting application of automatic techniques is the automatic uranium analyser which has been developed for uranium analysis of process streams from an ion exchange plant. Initially this unit is being used to provide a monitor for manual control information, but it has potentiality for automatic control. The instrument[4] which is shown schematically in Fig. 3, employs an absorptiometric technique for the determination of uranium-ion concentrations in aqueous solutions. Contemporary batch samples are taken automatically in cyclic order from process streams, separately treated with aqueous ammonium thiocyanate and the resulting colour complexes are analysed by an ultra-violet absorptionmeter. Volumes of samples and chemical reagents are measured and controlled by capacitance level indicators and a record of the uranium-ion concentrations is continuously available with alarm indication if the concentrations vary unexpectedly. In one form of apparatus an accuracy of measurement of $\pm 3{\cdot}5$ per cent. was possible with a 0·1 gram per litre sample and the smallest detectable change of concentration was 0·002 gram per litre. Reliability has been excellent and there seems little doubt that these techniques can be applied to automatic control problems.

A special problem which arises in the atomic energy field is the handling of reactor fuel elements. If the re-cycling of active fuel elements is required, and this is considered likely, then remote control of the re-cycling and the fabrication will be necessary. This is therefore a problem where automation has a great deal to offer.

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[1] J. B. Harding and P. R. Robinson, A.E.R.E. Report N/R 1550, November, 1954.

[2] Forthcoming paper by C. N. Davey and R. L. Elliott in the *Journal of Scientific Instruments*.

[3] H. Bisby, E. Franklin and D. Taylor, Paper P.763, Proceedings of the Conference on the Peaceful Uses of Atomic Energy, August, 1955, vol. 6, pages 704-711.

[4] It is described more fully in a forthcoming paper in the *British Journal of Applied Physics*, entitled "An Automatic Analyser of Uranium Content in Process Streams."

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DANGER WARNING TAPE

A new type of self-adhesive strip material, called Lasso Zevra warning tape, marketed by Smith and Nephew, Limited, Bessemer-road, Welwyn Garden City, Hertfordshire, is being used to draw attention to potential danger spots in and about works, etc. Printed in vivid yellow and black diagonal stripes, the tape is employed to give warning of high-voltage cables and fuse boxes, low girders and beams, scaffolding, isolated pillars in workshops and stores, walls which project dangerously from the normal line of buildings, and other danger points. The warning stripes are underneath a fine transparent film, so that they maintain their brilliance and are protected from abrasion, moisture, acids and alkalis, and other deteriorating influences.

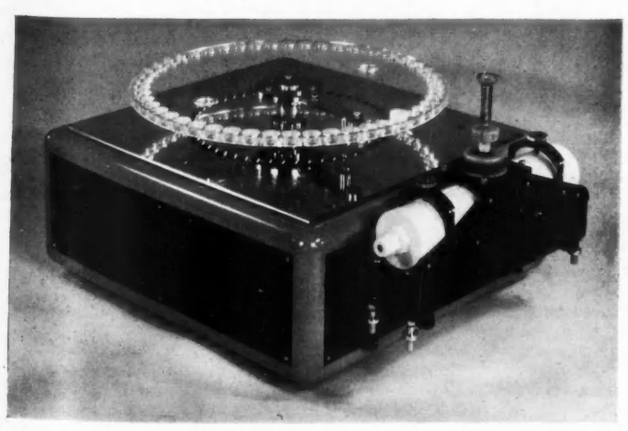


Fig. 2 (below) In the separation of rare earths in fission product analysis, the collecting bottle is automatically changed for each fraction by this apparatus, which will take 50 bottles.

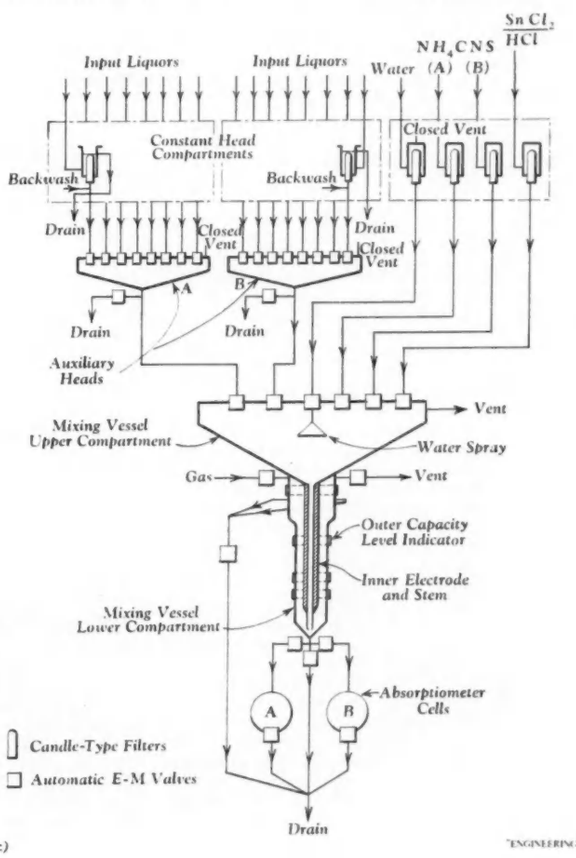
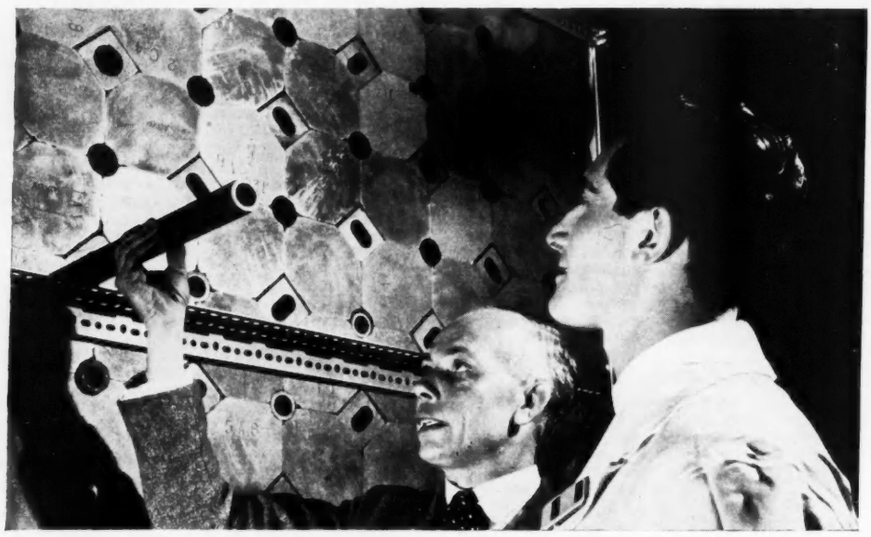


Fig. 3 (right) The uranium ion content of aqueous solutions can be automatically determined by the apparatus, shown here schematically, using an absorption technique.

Book Reviews



To understand fully the problems of nuclear engineering some knowledge of nuclear physics is necessary. The illustration shows an instructor at the Harwell Reactor School explaining how neutrons are slowed down by a moderator, and their speeds measured.

FUNDAMENTALS FIRST

Nuclear Physics. By DR. IRVING KAPLAN. *Addison-Wesley Publishing Company, Incorporated, Cambridge* 42, *Massachusetts, U.S.A.* (8.50 dols.)

During the past ten years there have been wide developments in the field of atomic energy, and during the next ten years we can expect many more, particularly in connection with the industrial development of atomic energy. In this country, for example, we should see the completion of the first part of the Central Electricity Authority programme of nuclear power station construction. Atomic energy is, in fact, passing much more from the province of the physicist and chemist into that of the engineer.

Engineers are therefore finding it increasingly necessary to familiarise themselves with this new subject, and the more enlightened have started at the beginning by undertaking a course of reading in the basic subject, namely nuclear physics, and may therefore welcome advice on a book for initial study. The present book by Dr. Kaplan may be the answer. It requires no more from the reader than a two-year course in college physics and a familiarity with integral and differential calculus, and yet the author manages to give a clear and readable account of most of what is now known as elementary nuclear physics, plus an introduction to nuclear technology.

The book is in three parts. The first part deals with the background of nuclear physics and, starting with the chemical foundations of the atomic theory, includes chapters respectively on: atoms, electrons and radiation; the nuclear atom; X-rays and atomic structure; the quantum theory of radiation; the special theory of relativity; and the atomic spectra and atomic structure. This is an imposing list of topics, but the subject is developed in an interesting and even fascinating manner, and the reader is quickly and easily transported through this background knowledge.

The second part of the book, amounting to about half the total, deals with the physics of the nucleus. The approach is descriptive throughout and the difficulties of the student are recognised and in most cases avoided. The first chapter in this second section deals with the constitution of the nucleus, explaining the failure of the proton-electron hypothesis and its replacement by the proton-neutron hypothesis, and the various properties of the nucleus, magnetic and electric moments, statistics and parity. After this follow chapters on isotopes; natural radioactivity and the laws of radioactive transformations; artificial radioactivity; alpha-decay; beta-decay; gamma-decay; nuclear reactions; and finally a chapter on nuclear forces and nuclear structure. This latter chapter is rather short and the subject matter perhaps too condensed, but this is in any case not a subject of the first importance for the engineer. The chapters on the experimental matters, artificial radioactivity and nuclear reactions are particularly well presented.

The third section of the book deals with special topics and applications, and should form a suitable introduction to those readers who hope to study some aspect of nuclear technology at a later stage. In this section there are chapters on neutron physics; nuclear fission; nuclear energy sources, for example, the nuclear reactor; particle accelerators; and isotope separation.

The book is well printed and illustrated. It is probably not ideally suited to the needs of the man aiming to specialise in physics, but for the engineer and the general reader the treatment given is excellent and provides a readable and valuable introduction to the subject. It can be recommended.

BURIED SUCCESS

Development of Power Cables. By P. V. HUNTER and J. TEMPLE HAZELL. *George Newnes, Limited, Tower House, Southampton-street, Strand, London, W.C.*2. (25*s.*)

As Sir Vincent de Ferranti remarks in his foreword to this interesting book, it is the successes of cable makers which lie quietly interred and their mistakes which are dug up and exposed to the penetrating ordeal of scientific analysis and publicity. Nevertheless, progress has necessitated the periodical unearthing of many cables of historical interest; and it was realised by Mr. Hunter, when he was preparing his presidential address to the Institution of Electrical Engineers in 1933, that these would be inevitably lost if samples were not quickly acquired and preserved.

A collection of examples of the cable-making art was therefore made, in the course of which much interesting historical information came to light. The present book is one result. Another is, of course, the Hunter-Hazell collection of power cables, which is housed in the Science Museum at South Kensington.

The authors begin with an account of early development, prior to 1880; and it will probably come as a surprise to many that the first cable designer, if not manufacturer, was Torricelli, the inventor of the barometer. He was followed in the Eighteenth Century by other pioneers, among them Don Francisco Salva of Barcelona, who in 1798 successfully transmitted signals over a 26 mile line between Madrid and Aranjuez and suggested that " the wires can be twisted together into one strong cable laid in subterranean tubes." Rubber insulation was first suggested by von Schilling, and guttapercha made its appearance in 1843, being subsequently used by Siemens and by Wheatstone in this country for submarine telegraph work after a system of watertight sheathing had been devised. Vulcanised rubber made its appearance at about the same time, although it did not come into prominence until arc lighting was developed in the 'eighties of last century.

The development of power cables may, however, be said to have been begun with the advent of the incandescent lamp. This called for conductors which could be installed in runs of considerable length. Of the methods available for this purpose at that time, one was to use a stranded conductor, covered before dispatch with a flexible waterproof dielectric. Insulation of this type had to be both stable in service and impervious to moisture, two properties which were obtained by employing vulcanised bitumen, an insulant which was successfully developed by the Callender family. Another method of using bitumen was introduced by Edison, and oil-filled jute was employed by a number of workers. Alternative methods of transmitting power were the strip systems due to Crompton, Kennedy, Latimer Clark and Muirhead.

The outstanding advance was, however, due to Ferranti, who, as is well known, used paper impregnated with ozokerite for transmitting power from Deptford to the West of London at a pressure of 10 kV, a pioneering effort which, with the correlated developments which took place, is fittingly treated in great detail by the authors. In this connection it is interesting to read that Ferranti was considered by his employers to be " lacking in prevision "—a charge which it would now be difficult to sustain against that great engineer.

By the end of the century several installations of paper-insulated cables operating at 11 kV were in use, and in the meantime the introduction of polyphase transmission had created a demand for three-phase cables. Increasing loads, with the consequent growth of transmission voltages, led to the development of belted cables (which soon exhibited drawbacks), of the screened cable (which resulted from Hochstadter investigations into stress distribution) and later to the employment of the oil-filled and Oilostatic systems and of the various types of gas pressure cables. It is at this point that the authors perhaps wisely, but certainly disappointingly, call a halt on the grounds that it becomes increasingly difficult to view more recent events with objectivity.

Nevertheless under the heading of recent developments they have something to say on the revival of the use of aluminium both as a conductor and as a sheathing material. They also give some up-to-date information about the submarine transmission of power, a matter which is likely to assume greater importance in the near future, as well as on the 380 kV cables short lengths of which are in use in Sweden. The experience gained with these might possibly soon be of value in this country. As regards the future, too, they prophesy that the next major advance seems likely to be an entirely new insulating material.

It would be unbecoming, and indeed it is unnecessary, to criticise this book on points of detail. We can only recommend that it should be read—an easy task owing to its excellent style.

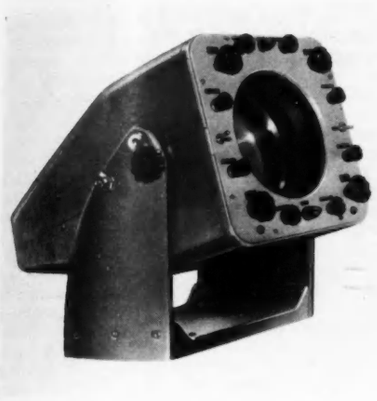


Fig. 1 Display unit showing controls.

SHIP-BORNE RADAR

A High Performance Compact Design

To obtain reliability under all conditions of service, full high power performance and high definition as well as low weight with small size Kelvin and Hughes Limited, Knotts Green, Leyton, London, E.10, have designed a new model of ship-borne radar equipment.

The transmitter of this equipment measures only 16 in. by 15 in. by 9 in. and is designed for bulkhead or deckhead mounting. It incorporates a magnetron with an output of 60 kW at a recurrence frequency of 1,100 p.p.s. Two pulse lengths are used to provide solid paints at the long ranges and clear pictures at the short ranges. As magnetic techniques are used, valves are unnecessary with the result that the modulator is simplified and reliability improved. Tuning of the local oscillator is facilitated by the provision of a neon lamp. The radio frequency head includes a broad band cell.

The scanner unit, which is illustrated in Fig. 2, incorporates a 6 ft. end-feed slotted wave guide of the radiator type, which eliminates the necessity for the conventional reflector. The use of this system considerably reduces the wind resistance and weight, improves the electrical characteristics and eliminates the sidelobe echoes.

The display unit, which is shown in Fig. 1, above, incorporates a 9 in. cathode ray tube, the angle of view of which can be adjusted to suit individual requirements. There are five range scales: from 1½ to 3 miles, 6 miles, 12 miles, 24 miles and 48 miles. As regards general design, printed wiring technques are used and all the units are quickly removable for servicing or replacement.

The controls are, as will be seen, arranged round the built-in viewing hood and each is provided with an illuminated identification panel. To obtain optimum results under "clutter" conditions both differentiating and swept gain control are provided. A variable range marker as well as calibration rings are available for range measurements. The local oscillator tuning indicator, the range marker dial and the indication of the range in use are all visible inside the viewing hood.

All the power supplies, other than the valve heater transformers which are located in the individual units, are housed in a small box on which the start/stop switch, the standby switch and the aerial control switch are also mounted. The motor-generator, which is also of compact design, is arranged for direct-on starting and its voltage is automatically controlled by a magnetic amplifier regulator.

Fig. 2 A 6 ft. end-feed slotted wave guide of the radiator type is used on the Kelvin Hughes new marine radar equipment reducing wind resistance and weight and improving characteristics.

★ ★ ★

SPEEDING UP UNLOADING OF BRICK KILNS

The problem of rapidly removing heat from brick kilns after the firing period, has been solved in a simple manner by the Cattybrook Brick Company Limited, and, as a result, the bricks in the kiln can be drawn some 24 hours earlier than was formerly possible.

The company's kilns at Shortwood, Mangotsfield, near Bristol, are of the continuous type, one having 16 chambers with a capacity of 15,000 bricks per chamber and another having 20 chambers with a capacity of 9,000 bricks per chamber. The firing period is approximately 2½ weeks and the chambers are now cooled by placing over the fuel feed holes an aerofoil fan supplied by Woods of Colchester, Limited. This extracts heated air and draws in cool air through the chamber entrance. The draught through the kiln quickly reduces the temperature sufficiently to enable men to enter the kiln and work in comfort. The fan is mounted on an angle-iron trolley and is wheeled across the roof of the kilns as shown in the illustration.

The fan is a 15 in. single-stage unit running at 2,850 r.p.m., and it is fitted with a short length of duct which tapers to the diameter of the fuel-feed hole. As the fan deals with air at a fairly high temperature and is exposed to the weather, the motor is treated for air temperatures of up to 250 deg. F., and for operating in saturated atmosphere. Glass-fibre insulation and a heat-resisting impregnation and finish, including silicone materials are used where applicable. The saturated-atmosphere treatment includes special cabling, the drainage of the carcase and the protection of all interior and exterior surfaces, as well as special impregnation.

Three fans are in use at the Cattybrook Works and after 12 months' running, extracting heat from the kilns in all conditions of weather, it is stated that there are no signs of deterioration to be seen.

Aerofoil fan used for cooling brick kilns after the firing period. When placed over a fuel feed hole, the fan draws cool air through a chamber and rapidly creates a comfortable working atmosphere therein.

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INSPECTING PLASTICS LAMINATES

Improved means for inspecting glass-reinforced plastics laminates by a non-destructive method have been devised as a result of research conducted at the Battelle Memorial Institute, Columbus, Ohio, U.S.A. The techniques developed were described in a paper presented by Mr. A. J. Schwarber, Jr., of the Institute, and Mr. W. R. Graner, of the United States Navy Bureau of Ships, at the 11th conference of the Society of the Plastics Industry, held in Atlantic City, New Jersey, in the early spring. The new techniques utilise ultrasonic waves or electrical energy to determine thickness and also to detect flaws.

When using the ultrasonic method, the specimen is passed between a crystal producing ultrasonic waves and another crystal receiving them. Such an inspection must be conducted in a suitable sound-transmitting fluid, such as water or oil. The receiving crystal produces an electric signal proportional to the ultrasonic sound waves impinging on it. Any defects or discontinuities in the specimen are indicated by a decrease in the signal received. The method, which is limited to the inspection of small parts in the laboratory, is stated to be extremely sensitive and capable of detecting readily defects in panels up to ¼ in. thick.

Another ultrasonic test described by Mr. Schwarber and Mr. Graner is based on the principle of resonant frequency. An instrument transmits ultrasonic waves of varying lengths, and hence frequency, to the specimen, and when the specimen receives that frequency which is characteristic of its thickness, it will resonate, producing changes which may be measured in the electrical circuit. Employing a special barium titanate transducer to impart the waves to the specimen, Battelle technologists have been able to measure the thickness of laminates with a maximum error of 8 per cent. in a thickness ranging from ⅛ to ½ in.

A dielectric test also employed utilises a capacitance-type probe which is a modification of a thickness gauge. The dielectric properties of a laminate specimen produce changes in the capacitance of a condenser. As the thickness of the laminate, and in some cases its resin content, change, the capacitance of the condenser changes. The resulting variation is registered in the oscillator circuit.

MEASURING VIBRATIONS

METHODS SUITABLE FOR MECHANISMS WITH FLEXIBLE COMPONENTS

Mechanisms which have vibrating members offer particular difficulties to the measurement of vibration in their rigid parts. This article describes a method by which these vibrations can be measured, and their frequency determined, in the case of some sieves which have a rotary motion.

Some of the most persistent problems occurring in the design of machinery of all sorts are those concerned with vibration. These difficulties are naturally increased when the successful operation of the mechanism actually depends on the deliberate production of a vibratory movement, as is the case with sieves and strainers such as those described in this article.

Vibration is not only the main cause of metal fatigue, often leading to fracture, but also of irritating and inconvenient noise. It is particularly important therefore in machines of this type to be sure that only the vibration actually required is generated, and that it is confined, as far as possible, to the parts of the mechanism where it is needed.

The principal difficulties arise when frequencies are generated that are near enough to the natural frequency of any of the parts to cause resonance. When resonance occurs, the amplitude of the vibration will rise sharply and, accordingly, all the effects of vibration will be greatly magnified.

The principal factors defining any vibration are frequency and amplitude. From these, two other important parameters may be derived, namely, velocity and acceleration. Any variation in the first two will be reflected by corresponding alterations in the second derivative pair.

From a practical point of view the frequency of vibration is important, but chiefly indirectly. If it falls within the range 18 to 18,000 cycles per second, it will become audible as a sound. Except on musical instruments, bells and similar products, sound resulting from operational vibration must be considered as an unwanted by-product. Moreover, if the frequency should happen to coincide with the natural frequency of any part of the machine, then it will result in resonance, and so cause the amplitude of the vibration to increase greatly. This in turn will cause the velocity and acceleration of the vibration to increase proportionately and thus lead to premature failure of the component.

ACCELERATION DANGERS

Analogies for these four factors can be drawn from the behaviour of a wrist watch. First, as regards resonant frequency: when the balance wheel first starts to swing, at a frequency of oscillation governed by the physical characteristics of the wheel and hair spring, it moves over a very small arc. As impulses which coincide with the timing of the oscillations are, however, given to the wheel at each end of its travel by the escapement mechanism, the amplitude of the arc increases at each cycle until, from one cause or another, the limit is reached. Had the impulses not been applied in time with the natural rhythm of the wheel, this regular building-up of the oscillations would not have occurred, and the amplitude would have varied according to whether the impulse had been applied so as to assist or to oppose the existing movement. As, however, the natural frequency and the applied frequency are in tune with each other, the balance wheel can be said to be in resonance with the impulses, with resulting increases in the amplitude of oscillation.

Next, consider the question of the amplitude of the applied vibration: vibrations large in extent (or amplitude) but slow in repetition (or velocity and acceleration) that affect the watch as a result of wearing it aboard ship at sea have little effect on its time-keeping qualities. The far smaller movements at a much higher frequency (and therefore of increased velocity and acceleration) that arise from wearing the watch while operating a compressed-air hammer will, however, almost certainly affect it adversely.

As with most mechanisms, mere speed of movement—the velocity—is not likely to have any ill effects on the watch, but very rapid acceleration or deceleration will certainly throw it out of adjustment. It may even cause parts to bend or break or in extreme cases the whole watch may disintegrate.

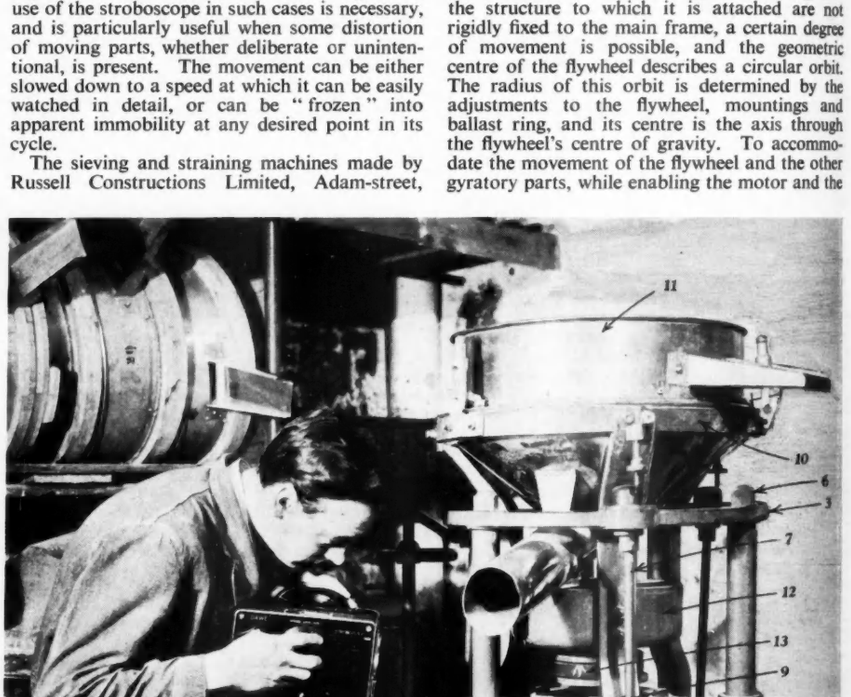
Like all such "pictorial" representations, this analogy must be accepted with reserve, but it serves to differentiate between the effects of the three parameters of vibration, namely, displacement, velocity, and acceleration, and to make it clear why it is desirable to measure more than one of them in the course of vibration testing.

ANALYSING THE OPERATION OF SIEVING EQUIPMENT

It is not enough merely to measure the amount of vibration present; its source must also be identified before any cure can be undertaken. While this can sometimes be done with the vibration meter alone if this is used with skill, more often some other equipment is needed. Direct observation of moving parts will frequently provide the answer but, if their movement is rapid, unaided observation will not help. The use of the stroboscope in such cases is necessary, and is particularly useful when some distortion of moving parts, whether deliberate or unintentional, is present. The movement can be either slowed down to a speed at which it can be easily watched in detail, or can be "frozen" into apparent immobility at any desired point in its cycle.

The sieving and straining machines made by Russell Constructions Limited, Adam-street, London, W.C.2, are a good example of the type of machine to which testing of this nature can be profitably applied. Several of these machines have been described in ENGINEERING, vol. 177, page 370, 1954. The general principle of operation is similar in all the models. The stand model, shown in the accompanying illustration, has a solidly built frame, mounted on three small wheels. The frame carries the motor, the shaking mechanism and the sieve. The frame itself is made up of three castings: the base ring (1), the motor mounting web (2), and the upper ring (3), all bolted together by three stout columns (4). These components together with the wheels and the motor (5), comprise the stationary part of the machine. Fixed to the upper ring are three equally-spaced compressed-rubber anti-vibration suspension mountings (6), each carrying a suspension rod (7), fastened at its lower end in a compressed-rubber bush (8). The lower compressed-rubber mountings are attached to the bottom ends of the leg castings (9), which support at their tops the rim (10) carrying the sieve (11) itself. A casing (12) containing a flywheel, which can be adjusted for varying degrees of unbalance, is bolted to the legs near to their centre. The flywheel, which runs in ball-bearings, is driven from the motor through a flexible coupling (13). In addition, ballast rings of different weights may be attached to the lower end of the legs, below the resilient bushes (8) to enable the balance of the moving parts of the machine to be adjusted.

The flywheel, owing to its unbalanced state, endeavours to rotate about an axis that passes through its centre of gravity, and not about its geometrical axis. As the flywheel casing and the structure to which it is attached are not rigidly fixed to the main frame, a certain degree of movement is possible, and the geometric centre of the flywheel describes a circular orbit. The radius of this orbit is determined by the adjustments to the flywheel, mountings and ballast ring, and its centre is the axis through the flywheel's centre of gravity. To accommodate the movement of the flywheel and the other gyratory parts, while enabling the motor and the



Observing the distortion of the flexible driving coupling during operation. When at rest, the three chalk marks were in line.

TABLE I

Position of pick-up		Acceleration (in. per sec. per sec.)	Velocity (in. per sec.)	Displacement
A	Upper ring	210	0·18	0·00055
B		120	0·17	0·0007
C		200	0·17	
D		210	0·14	0·0005
E		130	0·11	0·00055
F		170	0·20	0·0004
R		1,500	7·0	0·044
S		280	0·48	0·0042
T		1,300	6·0	0·037
U		270	0·34	0·006
V		1,100	6·4	0·032
W		276	0·4	0·0037
L	Base ring	80	0·06	0·00018
M		105	0·09	0·0003
N		130	0·20	0·0012
O		170	0·18	0·0012
P	Wheels	130	0·22	0·0013

TABLE II

Probe attached at point →		A	M	U
Cycles per sec. ↓	Acceleration peak at →	49 c/s	343 c/s	49 c/s
		Per cent. of peak	Per cent. of peak	Per cent. of peak
24·5	Twice motor → speed	25	25	25
49		100	70	100
73·5		15	15	20
98	Seven times → motor speed	20	20	20
122·5		25	25	25
147		30	25	30
171·5		90	90	100
196		80	70	80
220·5		70	60	70
245		30	30	30
269·5		70	60	70
294	Fourteen times → motor speed	35	40	35
318·5		80	80	70
343		100	100	90
367·5		60	60	50
392		50	50	50
416·5		50	40	50
441	Fifty times → motor speed	50	40	40
465·5		25	25	25
686		20	20	20
882		20	20	20
980		20	20	20
1,225		90	80	60
1,347·5		80	40	80
1,470		20	20	20
1,739·5		20	20	20
1,862		30	20	30

Note.—All frequencies *not* listed here showed a level of less than 10 per cent. of the peak value.

fixed frame to remain stationary, the rubber ring of the flexible coupling is distorted during rotation. The lower coupling half simply turns about its centre, while the upper half, being attached to the flywheel shaft, has in addition the orbital movement around the axis of the machine. The two coupling halves remain parallel during operation. It is the gyratory movement which provides the sieving action while, at the same time, the method of flexible suspension and drive ensures that the least possible amount of vibration is transmitted to the motor and the frame, in spite of speeds of up to 3,000 r.p.m.

The adjustment that has been found by experience to give the best results is not the most even. A small degree of irregularity gives an improved rate of sieving, but too great a difference allows an undue amount of vibration to be passed to the frame and thence to the floor on which the machine is standing.

It was with the intention of determining the extent to which the vibrations produced are actually transmitted to the frame that the tests to be described have been carried out.

TEST EQUIPMENT USED

The instruments used in the series of tests that form the subject of this article were a Stroboflash, and a sound level meter, both made by Dawe Instruments Limited, 99 Uxbridge-road, London, W.5. The sound level meter was provided with a vibration adaptor, which enabled measurements of displacement, velocity and acceleration to be made on an instrument normally used for sound level measurement. This equipment, as can be seen in the illustration, is very compact. It is very simple to operate, and is as suitable for use in the factory as in the laboratory. In addition a frequency analyser made by the same firm was connected to the sound level meter to determine the frequencies at which the machine showed resonances.

The Stroboflash has a range from 250 to 18,000 flashes per minute and can thus "freeze" rotary or cyclical motions within these limits. This range can be increased in use to about 100,000 r.p.m. by use of multiples of the flashing rate. This means that if the speed is known within certain limits, the exact speed can be determined by arranging that the flash occurs at the same point not in every revolution, but in every second, third, etc., revolution. For example, if the speed of some rotating component is known to be between 40,000 and 50,000 r.p.m., and the appearance of freezing can be obtained with the stroboscope set at 15,000 r.p.m., then the speed of the component will be 45,000 r.p.m., the stroboscope having flashed once for every three revolutions of the component.

The sound level meter, which is battery-operated and fully self-contained, gives readings of from 24 to 140 dB above the threshold of hearing, at 0 dB equalling 0·0002 dynes per square centimetre of sound pressure. The response is substantially flat over the range from 25 c/s to 8 kc/s, which is the range of the audio frequency analyser. This latter instrument can be used in conjunction with the sound level meter both for sound analysis (with the microphone) or for vibration analysis (with the vibration pick-up). It can, of course, also be used with a vibration meter specifically designed for vibration testing, but that instrument was not used in the tests here.

Observations were made of the behaviour of the different parts of an experimental machine while running with a normal load. The test load chosen was tea, of which about 7 lb. were put into a sieve with a fine mesh, which allowed the dust to pass and retained the usable tea. The Stroboflash was used to watch the distortion of the flexible coupling during operation and, to assist in this observation, chalk marks were made across the three parts of the coupling: driving member (lower coupling half), flexible ring, and driven member (upper coupling half). The illustration shows this examination taking place, and the distortion of the ring can be clearly seen. Other parts examined included the suspension, and the Stroboflash was also used for checking the motor speed.

The next set of tests was of the sound levels in the neighbourhood of the machine to determine which of its parts produced the greatest noise. It was found that most noise came from the drumming of sheet-metal parts (sieve wall, funnel and delivery spout) but was remarkably low (70 dB) even close to these components. It was decided that this aspect of the machine was entirely satisfactory which bears out previous experience in this respect, and that no further attention need be paid to the question of noise. Since the ambient noise level of any surroundings in which this type of machinery is likely to be used is rarely less than about 75 to 80 dB, there would be no point in silencing the machine below 70 dB.

The vibration testing was carried out in more detail; results are given here in tabulated form. Readings were first of all taken at a number of points on the upper ring (3), and on the base ring (1). During all these tests the machine was running at 1,470 r.p.m. This speed was checked by the stroboscope at intervals throughout the testing period.

RESULTS OF THE TEST

Table I shows the figures for the three parameters of vibration obtained at the 17 selected points on the upper ring and the base ring, while Table II gives details of the frequency spectrum of three points. The figures for the other points so closely resemble those quoted that no purpose is served in reproducing them.

It will be noticed that the figures for the upper ring positions (A to F, and R to W inclusive) are higher in the neighbourhood of the Silentbloc supports (R, T and V), and that the highest of these is that nearest to the manoeuvring handle (R). This is probably due to the fact that the restraining strap is attached to the suspension rod and to the pivot of the castoring wheel so biasing the figures.

From this set of figures, it can be seen that all the frequencies producing appreciably high levels were direct multiples (2, 7, 14 and 50), known as "harmonics," of the rate of rotation of the motor, that is to say, 1,470 r.p.m., or 24·5 r.p.s. The highest figures indicate resonance of some part or parts of the equipment; for example, the resonance at 343 c/s was produced by the legs of the machine. Owing to the fact that the vibration of these parts was too great to be measured with any reasonable degree of accuracy with the machine running, recourse was had to another method. With the sound level meter fitted with its microphone, and the analyser still in use, the natural frequency of vibration of the legs was determined by analysing the note produced on striking the metal of the leg with a light hammer. The principal component of this note was found at 340 c/s, and this is sufficiently close to the 14th harmonic of the fundamental frequency (actually 343 c/s) to produce a resonant condition.

For several reasons, but especially as regards fatigue in metal parts, resonance is a most undesirable condition. It can be avoided by ensuring that the natural frequency of the parts affected is as far as possible from any of the harmonics of the fundamental frequency; in other words, it is necessary to retune the part so that it no longer resonates to the applied vibration. This is not usually a difficult process, and once the frequencies that are likely to affect any given part are known, the cure for resonance can be achieved quite readily.

OTHER APPLICATIONS

This series of tests was only one of many and, although the details will vary from case to case, the broad principles generally remain the same. Any type of mechanism, whether usual or unusual in its design, can be tested in this manner and records can be kept of the results. In this way, it can be ensured that anyone who uses the instruments and the records properly can reproduce the same effects. Test procedures and adjustments can be raised from the position of empirical methods, based perhaps on a foreman's instinct and memory, to a scientifically controlled system, giving regular and consistent results, and saving both time and trouble by making the effects of adjustment predictable.

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ELECTRICITY SUPPLY

During July, 1956, 4,923 million kWh were sold by the Central Electricity Authority to the English and Welsh Area Boards. This was an increase of 14·4 per cent. over the output for July 1955. When corrected for weather conditions and working days, the figure was, however, reduced to 8·2 per cent.

The amount of electricity sent out by the Area Boards during the same month was 4,748 million kWh and 175 million kWh were supplied direct by the Central Authority. The increases in the amounts sent out, compared with the corresponding figures for July, 1955, were 14 per cent. in the "mainly industrial" and 15·7 per cent. in the "mainly non-industrial" areas.

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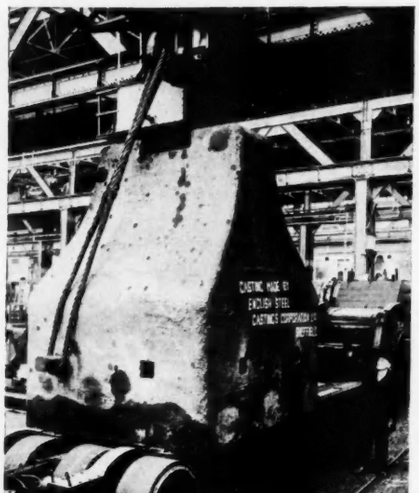
ELECTRIC TRACTION MANUFACTURE

For the past 36 years the Metropolitan-Vickers Electrical Company, Limited, has manufactured motors and generators for electric and Diesel-electric locomotives as well as multiple-unit trains, tramcars, trolley buses and other traction equipment at their works at Attercliffe Common, Sheffield. These works are now to be extended on a 21 acre site, which will double the existing capacity.



One-piece 143 ton cast-steel anvil block for 7 ton forging hammer, at the railway-wheel axle forge of Steel, Peech and Tozer, Rotherham.

MASSIVE STEEL-HAMMER BLOCK FOR ROTHERHAM FORGE

A steel forging-hammer block having a machined weight of 143 tons has been installed in the railway-wheel axle forge at the works of Steel, Peech and Tozer, Rotherham, a branch of the United Steel Companies, Limited. The anvil block, a one-piece steel casting, valued at £15,000, and seen in the accompanying illustration, was made at the Grimesthorpe steel foundry of the English Steel Castings Corporation, Limited, Sheffield, for B. & S. Massey Limited, Openshaw, Manchester, the builders of the 7 ton forging hammer. The new anvil replaces an 82 ton two-piece block consisting of an upper section of steel and a lower one of iron, the two being dovetailed and keyed together. In service, however, it was found that the two sections of the block were beginning to work loose, causing a deterioration in the quality of the axles being forged. In addition, maintenance costs were becoming excessive. An absolutely stable base is essential for high-quality forging, hence the reason for installing the new and heavier single-piece block, giving a ratio of block to hammer of 20 : 1, compared with a ratio of 12 : 1 with the former block.

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INFLATABLE WING AIRCRAFT

The M.L. Utility Aircraft Mark 1, illustrated below, has been designed by the M.L. Aviation Company, Limited, White Waltham, Berkshire, for operation from small landing fields, and to provide an aircraft of low initial cost which is easy to maintain and occupies little space for storage and transportation.

The wing is entirely without rigid bracing and retains its form by an inflated fabric envelope, in which pressure is maintained to provide a stiff aerodynamic surface. The wing can be deflated after flight, rolled up into a bag, and packed into the fuselage nacelle for transportation complete. The fuselage, being also very light, is easily manhandled by a single person and can be towed by a private car. The aircraft, thus dismantled could be accommodated in an average domestic garage. The wing can be re-erected in about half an hour.

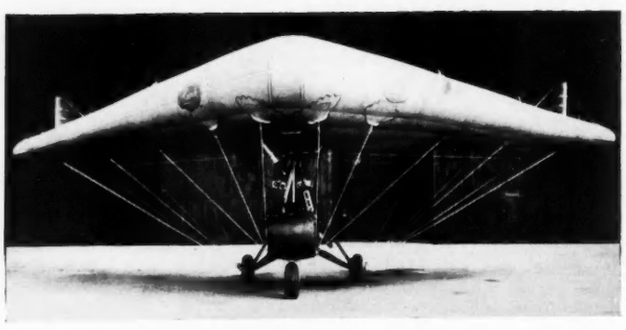
The overall length of the aircraft is 23 ft. 3 in. and its height is 10 ft. 6 in. The wing is of near-delta plan form with a span of 35 ft., a root chord of 17 ft. 6 in., a tip chord of 5 ft. 9 in., and an area of 500 sq. ft. It is provided with elevons which extend almost the entire span. It consists of an envelope of rubber-proofed fabric of which the top and bottom surfaces are connected by a number of porous fabric diaphragms running spanwise and extending continuously from wing tip to wing tip. These spanwise diaphragms maintain, by tension, the aerofoil profile, which is symmetrical and developed from N.A.C.A. 0024. The wing carries the fuselage by means of a series of straps and toggles secured to the under-surface. Flying wires attached to patches on the wing are secured to the fuselage and undercarriage members. The air pressure within the envelope is maintained by a built-in electrically-driven pump and relief valves.

The fuselage is mainly of wooden construction and has seating for pilot and passenger in tandem. The engine, a 50 h.p. Walter Mikron III, is behind the passenger and drives a pusher propeller.

The undercarriage is of the tricycle type with a track of 5 ft. 4 in. and a wheelbase of 7 ft. 1 in., with a swivelling nose wheel steered by a rudder bar. Parking brakes are fitted to the two rear wheels. Control in flight is solely by the elevons which are operated by a cable and lever system connected to an inverted control column suspended from the top of the fuselage superstructure.

The all-up wieght of the aircraft is 935 lb., and the weight empty is 450 lb.

The performance is as follows:—maximum speed (50 h.p.), 68 m.p.h.; cruising speed (35 h.p.), 58 m.p.h.; stalling speed, 30 m.p.h.; rate of climb at sea level, 740 ft. per minute; take-off run, 70 yards and distance to clear a height of 50 ft., 140 yards; endurance at cruising speed, 2½ hours; ceiling 5,000 ft.



For stowage in a small area, the rubber-bag wing of the M.L. Utility Mark 1 aircraft can be deflated and packed in the fuselage. In flight, pressure is maintained by a built-in pump.

A SHEFFIELD WIRE-ROPE WORKS

The firm of William Cooke and Company, Limited, was founded in 1862, and has carried on the manufacture of wire rope at Tinsley, Sheffield, 9, for many years. In time, however, these premises became increasingly congested and a new site was acquired from the Rotherham Borough Council on the Eastwood Trading Estate, which lies on the north eastern outskirts of the town on the banks of the River Don.

On this site has been erected a modern factory specially designed to provide an economic and efficient layout for the manufacture of a comprehensive range of wire ropes and having also offices adequate and suitable for research, sales, service and administration. The architect was Mr. W. K. Gill, of Chesterfield, and the main contractors, W. J. Simms, Sons & Cooke Limited, Nottingham.

The new factory was opened on August 21, by H.E. Sir Clifton Webb, K.C.M.G., Q.C., High Commissioner for New Zealand. In this connection it is of interest to note that, in 1911, a company, William Cooke and Company (N.Z.) Proprietary Limited, was established in Auckland, New Zealand, and is now stated to enjoy the largest single share of the wire-rope business in the Dominion. This company has, this year, changed its name to Cooke's New Zealand Wire Rope Company Limited, and has moved to new offices and works at Mount Wellington and has also occupied new offices in Auckland.

The main shop of the new Rotherham factory, which contains the machines for making strands from galvanised steel wire, and wire rope from the strands, has a clear floor area measuring 322 ft. by 132 ft., and is spanned without columns by lattice girders 10 ft. deep. The roof is of north-light construction and is insulated. The structure of the building is of steel frame which was supplied and erected by James Austin and Sons Limited, Dewsbury. Special precautions were taken in forming the foundations and the Franki Compressed Pile Company, Limited, have driven 150 piles on the site to an average depth of 25 ft.

At one end of the main shop are arranged extensive racks for the accommodation of coils of wire coming into the works and, here too, are machines for the inspection and mechanical testing of the wire. At the other end of the shop are further racks where reels of finished wire rope are stacked by fork-lift trucks. The measuring and splicing of ropes is also carried out in this part of the shop.

Two large oil-fired boilers have been installed for space heating, and radiant heating panels have been supplied and fixed by the Brightside Foundry and Engineering Company, Limited. A flat-roofed wing adjoins the main shop, providing accommodation for a research department, tool room, canteen and first-aid room. Fronting the factory is a two-stroey office and administrative block in grey Derbyshire facing bricks with two continuous stretches of windows. The floors and roofs are precast concrete beams and have suspended ceilings with hidden lighting. The accommodation includes a large entrance hall with a general office and staff dining room, and, on the second floor, there are offices, a dining room and a conference room for executive officers. Studded rubber tiles have been adopted extensively for the floors of the offices and the corridors.

A new "Engineering Division," established this year for the design and manufacture of prefabricated industrial buildings, is housed on a consolidated area of 25,000 sq. ft., on which have been erected two steel-framed buildings, each of 50 ft. span, the portal frames being of tubular welded construction of the firm's own design and manufacture. In these shops is being produced equipment involving fabrication in steel tube and other sections for use in the erection of factories, warehouses and offices and also for racking, pallets and railings. Recently the Iranian Customs Administration have placed a contract with the firm for buildings to form steel warehouses, the value being in excess of £100,000.

In conclusion it is of interest to record that the firm have produced machine-made horse shoes from iron bar in a number of sizes and patterns for many decades. During the war of 1914–18, the output of the shoes reached a total of upwards of 4,000 tons per annum. Although on a reduced scale, the manufacture of the shoes continues; prominent among them are those produced from aluminium bar and used for shoeing race horses.

TURBO-CHARGED MARINE DIESEL ENGINE

SULZER'S ELIMINATE SCAVENGE PUMP

Trials have recently been carried out at the maker's works at Winterthur in Switzerland, of Sulzer Brothers' nine-cylinder marine Diesel engine, type RSAD76. It is a two-stroke, single-acting turbo-charged machine of 760 mm. bore and 1,550 mm. stroke. It is of the cross-head type and is directly reversible. The one on trial was built for a freighter that is being constructed for Koninklijke Rotterdamsche Lloyd and has a rated output of 11,700 b.h.p. at 119 r.p.m. with a maximum of 13,500 b.h.p. It is shown in Fig. 1.

This engine is the first to be built at Winterthur including all the features of pulse turbo-charging and cross scavenging combined with the two-stroke cycle. The ordinary scavenge pump has been eliminated and scavenging and charging air are both supplied from the three turbo-blowers. Each turbine is supplied from three adjacent cylinders of the engine and the firing order allows full advantage to be taken of the energy in the exhaust pulses. As in the non-supercharged version, a stuffing box is fitted on the piston rod (originally in connection with the use of heavy oil as fuel) and advantage has been taken of its presence to use the undersides of the pistons as air compressors. During the downward stroke, the air below the piston is compressed through a non-return valve into a receiving chamber which in turn communicates with the cylinder through the scavenge ports. Consequently even at starting as well as when running on part load, under which conditions the turbo-chargers cannot supply air at sufficient pressure, scavenging and partial supercharging still occur. Even complete failure of the turbo-charging system will not reduce the speed available below 70 per cent. of normal. Air from the turbo-chargers passes through coolers before being admitted to the cylinders. The receiving chamber occupies the same position in the engine as does the lever-operated scavenge pump in the non-supercharged version.

One of the great advantages of the supercharged engine for marine work is the reduction in size (particularly in length) that is possible for the same output. On the RSAD76 special attention has also been paid to the other main point in marine practice—accessibility. The turbo-blowers are arranged below the upper gallery, as may be seen in the illustration, so that access to the cylinder covers is not impaired. For any of the running parts that have to be removed for inspection, special places have been provided on the engine for them so that the engine room itself is not encumbered. Similarly, crankcase doors are on hinges with safety clips so that they do not have to be removed from the engine, but only swung open to allow inspection of the crankcase. As examples of these "storage" arrangements, when the piston and rod have been withdrawn, they can be stood on the upper gallery with the rod projecting downwards between the engine and the turbo-charger. At the same time the connecting rod with the crosshead slipper can be laid down so that the slipper projects through the crankcase door. In a similar way the camshaft can be withdrawn on to the upper gallery on the side opposite to the turbochargers, and the chain-tensioning device has a fitment on the middle gallery. The cylinder head can be lifted clear and will rest on supports above its normal position. These arrangements allow easy inspection of all the moving parts.

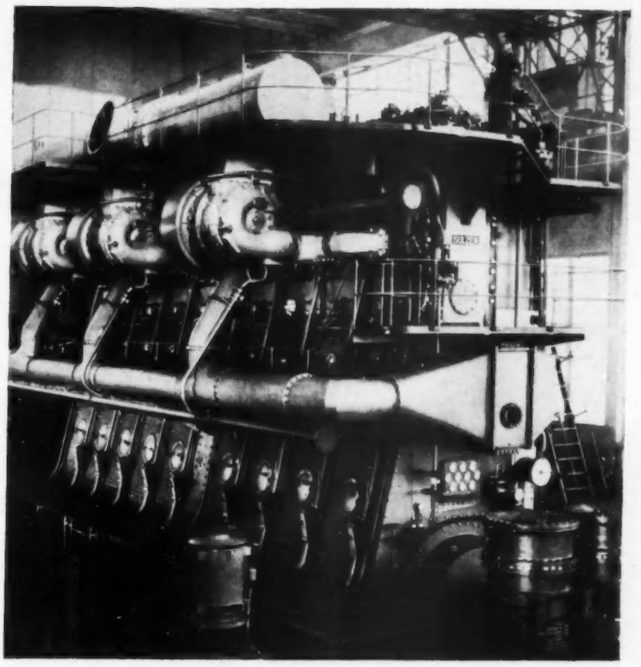


Fig. 1 On trial at Winterthur, the nine-cylinder turbo-charged engine gave the same output as the 12 cylinder normally aspirated version.

On these engines, the camshaft is chain driven at (or near) its mid point from the crankshaft. An oscillating valve controls the flow from the exhaust ports and is operated by a rod which extends across the engine to the camshaft. The valve is timed to close before the piston cuts off the scavenge ports, so that even in the non-supercharged versions the cylinder pressure is raised to that of the scavenging air. As mentioned earlier, these engines are direct reversing; control is by a quadrant lever for forward and reverse, and a rack-and-quadrant lever alongside for power regulation. These can be seen in Fig. 2. Starting is effected by compressed air and is quite satisfactory at pressures as low as two atmospheres as was demonstrated during the trials. It was also shown that the control lever could be moved without pause from "full ahead" to "full astern" and *vice versa*, the engine taking only a very few seconds to attain the changed condition. The manoeuvring period of the trials showed plainly the flexibility and exact control that could be obtained.

Although the trials at the works were for convenience carried out on standard Diesel fuel, in normal service the engine will run on heavy fuels. The fuel pumps are located at the level of the cylinder covers giving very short fuel pipes and allowing the use of low pump pressures. To compensate for variations in fuel grades, the injection timing can be altered during service. Performance curves are given in Fig. 3. As may be seen, a minimum fuel consumption of considerably less than 0·34 lb. per b.h.p. hour was obtained at approximately 90 per cent. of full load with an m.e.p. of about 91 lb. per sq. in. Even at 115 per cent. of full load (13,500 metric b.h.p. at 124·5 r.p.m.) consumption was still below 0·34 lb. per b.h.p. hour, and the exhaust was perfectly clean.

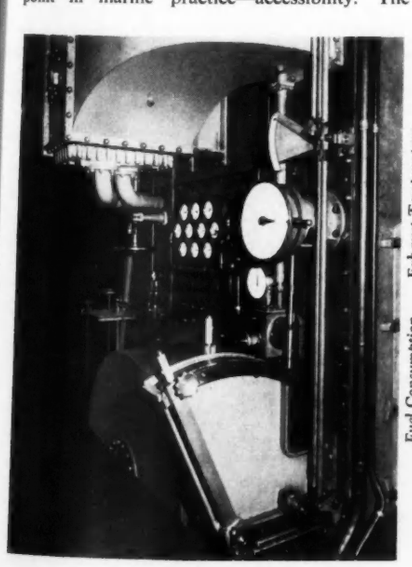


Fig. 2 Control is by two quadrant levers which govern the direction of rotation and the speed. Power output is shown by the quadrant above the main indicator.

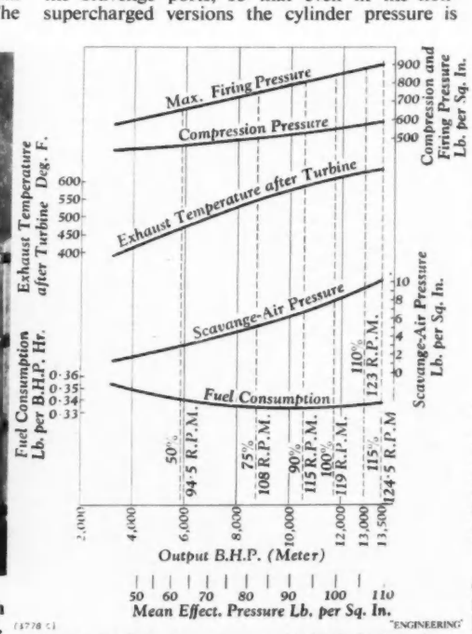


Fig. 3 Performance curves obtained during the trials.

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AERIAL CONSTRUCTION AT CRYSTAL PALACE

When the television transmitting station of the British Broadcasting Corporation was opened for service last March, use was made of a temporary aerial. It is now, however, hoped to bring the first part of the permanent aerial into service on September 10 and thus to increase the effective radiated power from 60 kW to 120 kW.

The new aerial is mounted at a height of 400 ft. at the top of the support tower, which forms the lower part of the permanent mast. It will therefore, be twice as high as the present temporary aerial and in addition will have greater horizontal directivity.

Fig. 1 Scale model of spiral casing and speed (scale 1:10) for the Niagara pumped storage scheme. Six Deriaz-type feathering Francis pump turbines are to be employed which can operate either as pumps or turbines.

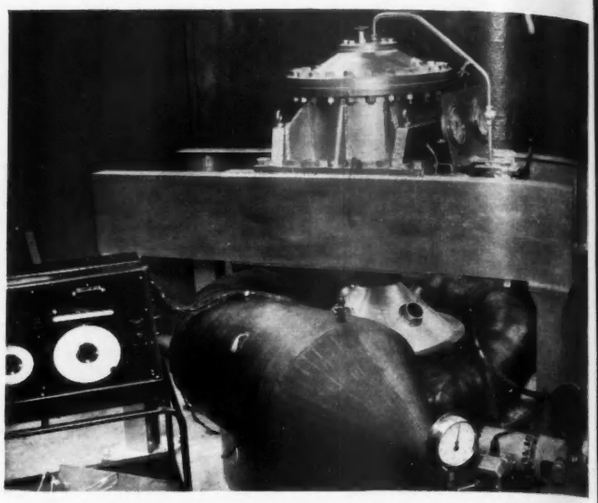

Fig. 2 During the testing of the model spiral casing for the Niagara scheme, about 1,000 separate strain gauge measurements were recorded under loadings simulating those occurring in the full size structure.

FOUNDATIONS FOR THE FUTURE

RESEARCH AND DEVELOPMENT IN A LARGE COMPANY

By G. F. W. Adler, B.SC.(ENG.), D.I.C., A.M.I.MECH.E.*

Industrial growth seems to proceed in two dimensions: in depth and breadth. As greater and greater demands are made on engineering products so their complexity increases and engineers must dip more deeply into scientific knowledge and methods, bringing to technology a depth it did not formerly have. Secondly, as firms increase in size so must they find more and more outlets for their talents and resources; thus a single company may be concerned with locomotives, instruments, hydro-electric plant, aircraft and atomic power. It follows that a growing fraction of a company's investment must be devoted to research and development, since production and design studies must be carried out both profoundly and over a wide field. This is well illustrated by the research activities of the English Electric Company, Limited, which is interested in many different branches of engineering. In this article the author gives a short account of research and development work currently in progress at the company's Whetstone premises.

Whetstone Works plays a prominent part in the research and development activities of the English Electric Company. It houses a range of laboratories and its specialised workshops produce much of the equipment, rigs and instrumentation required for research and development work at both Rugby and Whetstone. The laboratories fall broadly into two groups: (*a*) product department laboratories; (*b*) general laboratories. The work of an example from each group will be briefly described.

PRODUCT DEVELOPMENT

The four prime mover departments at Rugby and Whetstone (steam, water, and gas turbines and oil engines) and the recently established atomic power department each operate one or more laboratories the prime function of which is product development, that is, the evolution of the product to the optimum form. The water turbine department, for example, has a laboratory at Rugby for dealing with hydraulic and civil engineering problems as they affect the water turbine, and a further laboratory for mechanical development. The latter is situated at Whetstone and covers structural development, sealing problems and investigation of material properties. The structural work is of particular importance in a field where the rapidly increasing size and complexity of individual units combined with fierce overseas competition requires the application of the most advanced design techniques to achieve acceptable power-to-weight ratios.

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WATER TURBINE MODELS

Extensive application of welded structures (since as early as the 1920's) has made possible an analytical approach to water-turbine structural design, but this requires the backing of exploratory and confirmatory model tests. The technique of building and testing precise scale models of the often very large components of water turbines, has been highly developed at Whetstone. Fig. 1 shows an example, the 1 : 10 scale model of the spiral casing and speed ring for the Niagara pumped storage turbines. The hydraulic design of these machines, which can operate as pumps as well as turbines, is believed to be entirely new, and the associated structures set the designers a number of novel problems. Fig. 2 illustrates one phase of the test programme for the spiral casing model, which assisted greatly in determining the final design. It is interesting to note that, at one stage, approximately 1,000 separate electric strain-gauge measurements were being recorded, to obtain a full picture of the stress distribution in this complicated structure.

A number of components for the St. Lawrence turbines were subjected to exhaustive model tests. Three alternative model designs for the 28 ft. diameter composite top cover were tested and Fig. 3 shows one of the models in the laboratory. Every detail on these covers is true to scale, including welds and even machining allowances, to ensure accurate prediction of stresses and deflections of the full-size components. A 1 : 8 scale model of the regulating ring for the same turbines was also being tested under various loading conditions encountered in the turbine. A component associated with the turbine is the inlet valve. A butterfly-

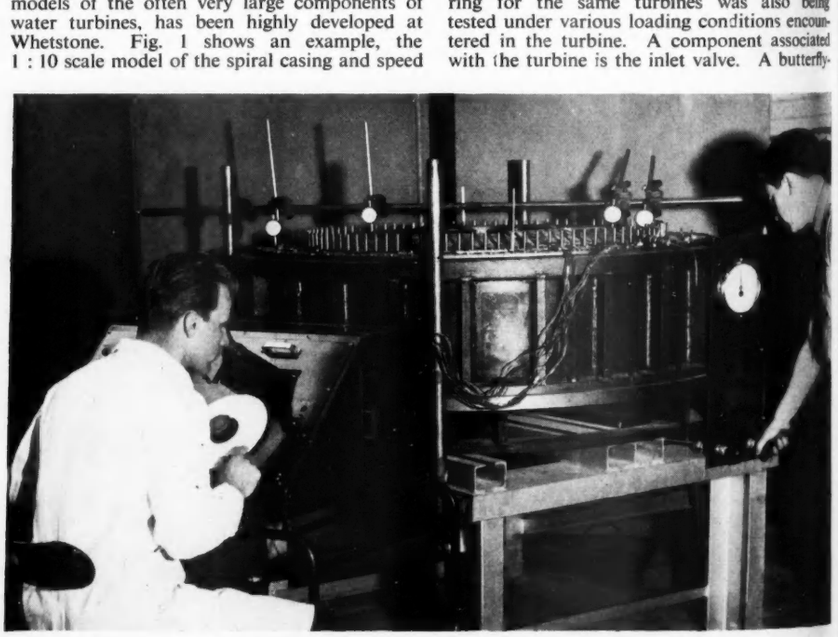

Fig. 3 A preliminary model (scale 1 : 6) of the composite top covers for the turbines of the St. Lawrence scheme was tested under hydrostatic loading and deflection and stress measurements were taken. Three models were built and the final design was considerably stiffer without any increase in weight. The 16 turbines will be of the Francis type, of 75,000 h.p. each.

type model valve is shown on test in Fig. 4, to determine stressing and deflections, sealing properties and operating torques.

SEALS AND BEARINGS

Much of the routine work of the laboratory is concerned with the development of seals of various kinds. A rig designed for life-testing large servo-motor seals under operating pressures up to 1,000 lb. per sq. in. is shown in Fig. 9. Service conditions are precisely simulated, pressure, speed of stroke and dwell being pre-set.

A further activity is the comparative testing of materials for special applications, as illustrated in Fig. 10. This is a bearing test rig, which simulates the heavy loading and slow rotary oscillating movement to which certain water turbine bearings (valve doors, guide and runner vanes) are subjected.

MECHANICAL ENGINEERING

The mechanical engineering laboratory at Whetstone was established in 1955 and has grown rapidly since. It deals with problems of a fundamental nature, usually of long-term duration. Its work may be broadly defined as applied research, and it therefore bridges the gap so often found between basic research as practised in the universities, and product development as normally found in industry.

The essential ingredients for such a laboratory are a high-grade staff, including, for balance, physicists and mathematicians as well as engineers, good computational facilities, and a first-class technical library. The mathematics section of the laboratory has at its disposal the company's DEUCE digital electronic computers, and it is proposed to install general purpose and specialised analogue computers. The library has grown rapidly and now provides an excellent technical information service for development and design engineers.

The mechanical engineering laboratory is organised on a subject basis, with separate Sections for the study of problems in: thermodynamics, heat transfer, fluid dynamics, lubrication, control, structures, mechanisms, vibration and mathematics. Each section has its own enclosed laboratory space, in addition to office accommodation, and a further area is set aside for heavy rigs which are too large or noisy for the laboratories. While the bulk of the work is related to Rugby and Whetstone products, much of it is of so wide a scope as to be applicable to the products of other works in the company. The laboratory is also available for work sponsored specifically by departments outside Rugby and Whetstone, and a number of such investigations are now under way.

OIL FILM WHIRL

A good example of a broadly-based investigation is the study of journal bearing lubrication and oil film whirl being undertaken by the lnbrication section. An analytical study, for which the DEUCE computer is being used, is backed by experimental work with a number of rigs, one of which is shown in Fig. 7. In this rig the behaviour of the oil film in a transparent bearing is being studied. Ultra-violet light is used in these experiments to produce fluorescence of the oil film.

The vibration section is engaged on a programme of study of critical speed of shaft systems and excitation forces. Model studies in the

Fig. 4 The novel constructional and sealing features of a prototype butterfly valve were proved by tests on a 1 : 5 scale model. Valves of this type are frequently encountered in water turbine installations where sealing properties and operating torques are important.

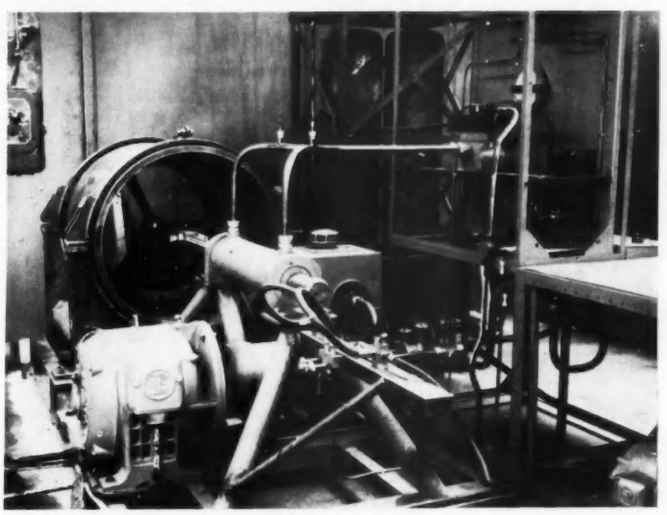

Fig. 5 Rubber seals, 2 ft. 6 in. in diameter, as used for servo motors and similar applications, undergo reciprocating tests on a rig that simulates service conditions. Speed of movement, stroke and dwell are automatically controlled for life testing. A number of such rigs are available in the laboratory.

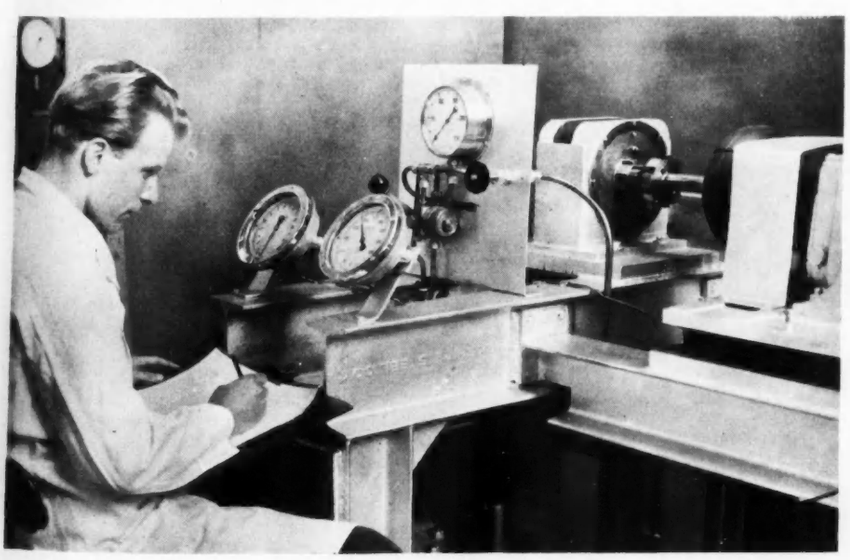

Fig. 6 In the bearing test rig, bearings under heavy load are subjected to slow-speed rotary oscillation, simulating conditions for inlet valve, guide vane and runner vane bearings of turbines. Friction torques are measured by an arrangement of a hinge-mounted drive and a load cell.

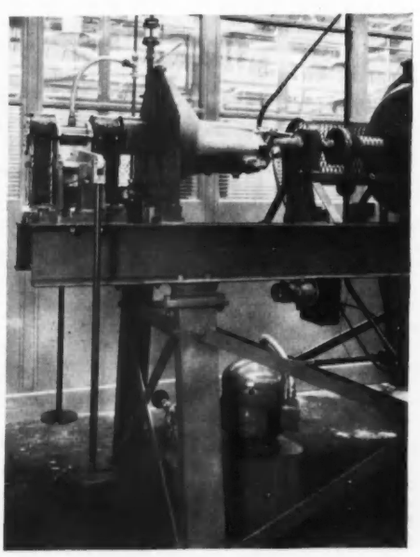

Fig. 7 The distribution of the oil film can be studied by illuminating a transparent bearing with ultra-violet light.

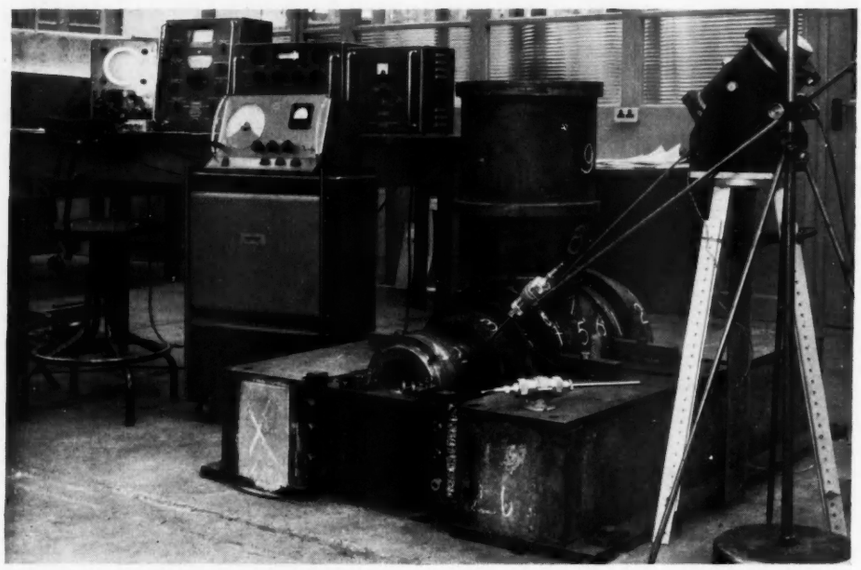

Fig. 8 Vibration measurements on model gas turbines can be made by exciting the rotor within its casing. In this way the effect of the stiffness of the casing on the critical speed of the rotor can be determined. Such work is part of a fundamental attack which is being made on the problem of critical speed prediction.

laboratory as well as field investigations are being undertaken. Fig. 8 illustrates this work, the equipment under test being a model of a prototype gas turbine.

Finally, the work of the control section may be quoted. This section is at present primarily devoted to a study of prime-mover governors, a field which nowadays requires intensive and expert treatment. In the relatively short period of its existence, the mechanical engineering laboratory has already demonstrated clearly that such an organisation can make a vital contribution to the solution of a company's engineering problems.

FLYING JEEP FOR AGRICULTURE AND GENERAL PURPOSES

CROP SPRAYING, SUPPLY DROPPING, COMMUNICATIONS, FREIGHTING

ENGINEERING's representative recently had the opportunity to fly in a new prototype agricultural aircraft, the E.P.9, designed by Edgar Percival Aircraft Limited, Stapleford Aerodrome, Essex. An aircraft intended for crop-spraying, top-dressing and supply dropping is required generally to fly fairly fast at low altitude, and to be capable of taking off and landing from small areas. A good forward and all-round view is therefore essential, and this has been achieved most successfully in the E.P.9 by the adoption of a high-wing layout, with the pilot placed high and well forward so that, when the aircraft is banked, he not only has unobstructed vision below the wing but is able to look over the top surface. To locate the centre of gravity in an acceptable position, and to ensure a good view over the nose, a horizontally-opposed six-cylinder air-cooled engine has been selected, and for this it has been necessary to go to the American market since, in the size required, the only British engines available are of the in-line type which would bring the centre of gravity too far forward.

The fuselage and tail boom have been so designed that when crop spraying or top-dressing is in progress, the liquid, which is discharged from a hopper situated behind the cockpit, is kept clear of the tail end of the fuselage and thus reduces substantially the cleaning operations necessary with conventionally shaped aircraft. The hopper can be filled through a detachable panel in the roof.

Although designed primarily for the agricultural field, it can fulfil various alternative civil and military roles, such as ambulance duties, communications, photographic- and geophysical survey, and freight carrying. As a passenger machine, it can carry five people as well as the pilot. In the ambulance version, two stretcher cases, one walking wounded and one attendant can be carried; it is the lightest aircraft capable of this work, and is under consideration by the British Army, the Royal Air Force, and the Royal Australian Air Force.

As a freighter, a cargo space of 185 cub. ft. is available with a floor area of 45 sq. ft. The low loading platform, coupled with the large cargo space, allows the transportation of sheep or other small animals. A large rear-loading clam-shell door allows standard 44 gallon petrol drums or bales of wool to be rolled in.

The E.P.9, a robust, simple machine, is powered by a Lycoming GO-480-B horizontally-opposed six-cylinder wet-sump engine of 270 h.p. driving a Hartzell HC-82X20-1B constant-speed airscrew of 7 ft. 6 in. diameter. The four engine-cowling panels are fitted with quick-release fasteners. The wings are of light-alloy construction, with a single spar and leading-edge torsion box.

The fuselage frame is of welded steel tubing, suitably protected, which has been found to provide the most effective construction for resisting the corrosive effect of agricultural fertilisers and sprays. A heavy tube frame immediately behind the pilots' seats takes the main wing spar and undercarriage loads. The cockpit accommodates two pilots with dual control. The pilots' seats are stressed to withstand 25*g* and are placed on a level above the engine and the load for maximum safety.

The undercarriage is of Percival design, to withstand a vertical velocity of 9 ft. per second, and, because of its long travel, it is claimed to have better energy-absorption characteristics than many deck-landing undercarriages designed for 11 ft. per second. Floats can be fitted for marine operation should the aircraft be required to carry out any such tasks.

In its agricultural capacity, the E.P.9 has an all-up weight of 3,980 lb. and can carry a useful load of 2,080 lb. The aircraft has a span of 43 ft. 6 in., an overall length of 29 ft. 6 in., and a height of 8 ft. 9 in.

At full load it will take off in 115 yards and climb at a rate of 990 ft. per minute. The maximum continuous speed is 140 m.p.h., and the economical cruising speed is 118 m.p.h. The aircraft has excellent slow-flying qualities and stalls very gently at about 33 m.p.h.

The E.P.9 is in production, and the first production aircraft, which has already flown, has been ordered by a New Zealand company, Manawatu Aerial Top Dressing Company, Limited, Palmerston North. It will be shipped to New Zealand in the S.S. Gothic in September in time for an international agricultural aviation exhibition sponsored by the Aviation Industry Association of New Zealand, which is being held during the Seventh International Grassland Congress in November. It will afterwards be used in a planned scheme to drop over half a million tons of fertiliser a year in New Zealand to open up barren ground for grazing in order to increase the country's meat production. Further E.P.9 aircraft are to go to New Zealand later, and orders are expected from Australia, Belgian Congo, Hong Kong, Iran, South America, Sudan and Zanzibar.

The Percival E.P.9 aircraft, designed primarily for agricultural uses, can carry 1 ton of fertiliser in a hopper installed in the fuselage aft of the pilot. Alternatively it can carry five passengers, two stretcher cases or freight.

ATOMIC REVIEW

Material Progress

Changing materials by irradiation—Radioactive isotopes for checking and testing—Supplies of iodine 131, *carbon* 14 *and caesium* 137*—Separating refractory metals by sublimation—Zirconium and hafnium—Separating heavy water by crystallisation—Thorium source?*

Irradiation Processes

A specially designed laboratory, believed to be the first in the British rubber industry, for the irradiation of rubber and plastics, has been completed at the Dunlop Research Centre, Birmingham. For a considerable time, irradiation of rubber and plastics has been a feature of the Dunlop research programme, and they will now be able to carry out a planned scheme of research. Work with a 100 curie source of cobalt 60 supplied by Harwell is about to begin, and later a full source of about 1,000 curies will become available. For various reasons it was felt expedient to begin with an isotope source, but installation of an electron accelerator has not been ruled out. The effects of ionising radiations in bringing about chemical changes, of which polymerisation is but one example, have been known for more than a generation, and since the war much work has been done by Dr. A. Charlesby and others on rubber and plastics in particular. The fact that irradiation by gamma rays from a radioactive source can cause cross-linking of the molecules suggests possibilities of carrying out vulcanisation and other reactions which may not easily be attained by other methods; and the opportunity of dispensing with ordinary chemical methods or of vulcanising previously incompatible or non-vulcanisable materials, promises new types and ranges of synthetic polymers. Although it is impossible to say yet whether the effect on the rubber and plastics industry of the by-products from nuclear reactors will be as far reaching as the stimulus of gas-industry by-products was on the dye-stuffs industry, the cases are nevertheless to some extent parallel. In the new laboratory protection from lethal gamma radiation is provided by 4 ft. thick concrete walls and a door which can only be opened when certain interlocking devices register that it is safe to do so. Mirrors enable experiments to be performed in safety. Special means of arranging specimens and sources are provided, and Fig. 1 shows a close-up view of source tubes and samples ready for irradiation.

Recent purchases of particle accelerators and the already considerable usage of radioactive isotopes by sections of the oil industry point to the part that nuclear techniques can play in the development of new oil products. Small quantities of petrol and other oil products have been prepared in the United States by exposing oils to gamma radiation emitted by a cobalt 60 source. The main economy of using such techniques is likely to be in heat saving, since with normal refinery processes temperatures as high as 600 deg. C. may be required at certain stages. Not only may these experiments lead to new oil cracking processes, but new materials too may be developed.

Not long ago the United Kingdom Atomic Energy Authority announced that it had consented to irradiate diamonds for commercial purposes. It has been known for over 50 years that colour changes can be achieved in this way and various different effects may be produced by radiations from particle accelerators, nuclear reactors and artificial radioacitve isotopes. Diamonds irradiated in a reactor turn green and, if heat treated subsequently, brown. Radiation from an accelerator may induce a blue or blue-green colour. Radioactivity of diamonds irradiated in a reactor decays to insignificance in a few days. Inquiries should be addressed to the Technical Irradiation Group, Isotope Division, A.E.R.E., Harwell.

Tests and Checks

In the Enrichment Laboratory of the Institute of Mineral Fuels (an institute of the U.S.S.R. Academy of Sciences) a series of experiments has been in progress since 1953 in connection with the use of radioactive isotopes for coal enrichment and the automatic handling of raw coal. As a result, it has become possible to elaborate methods of using gamma radiation for the solution of such problems as high-speed checking of ash content in coal-enrichment products, automatic sorting, and the dry enrichment of coal according to its ash and iron content. The use of gamma rays is based on the fact that the degree to which they are absorbed by coal depends on its density and composition. The aim is to reduce the ash content (comprising mainly SiO_2, Al_2O_3, Fe_2O_3, CaO and MgO). For this purpose it has been shown that best results follow from the use of gamma radiation with an energy of less shan 0·1 MeV; cobalt 60, selenium 75 and thallium 204 have been tried, but thallium proved the most satisfactory since it has a soft gamma radiation with an energy of 0·076 MeV The results obtained were used in the first place for controlling the ash content of enrichment products and for the mechanisation of screening. To develop a suitable screening system, a model was made representing a conveyor belt at the end of which was fixed on one side an ampoule containing a radioactive source and on the other a scintillation counter consisting of a scintillator (sodium-iodide crystal) and an electron multiplier. The scintillation counter is connected to an electron block having a thyratron relay which controls a solenoid. This turns a shutter to head the pieces of coal in one direction and dirt in another. Coal and dirt ranging in size from 50 to 100 mm. have been effectively sorted (*Vestnik Akad. Nauk*, 2, 1956.)

In the United States, too, radiation techniques are in widespread use. Recently the Carborundum Company have announced that nuclear gauges incorporating radioactive isotopes have been employed in the continuous-strip production of coated abrasives, a vital requirement of which is to ensure that the abrasive coating is well oriented. Five gauges are used. The first measures the weight of the backing; the second measures the backing plus the adhesive; the third measures the backing plus adhesive plus abrasive; the fourth repeats this last check but at this point the material has passed through a festooning rack and has lost most of the solvent in the adhesive; and the fifth measures the additional weight of adhesive applied at a sizer. Each gauge can be located at any spot across the width of web by means of a button. In this case strontium 90 serves as the radioactive source, and is contained in a sealed capsule located in the lower jaw of the plant U-frame; a radiation dectector (a special form of ionisation chamber) is fitted in the upper jaw. Strontium emits beta radiation (electrons) and the quantity reaching the detector is inversely proportional to the mass of material in the measured area. Continuous sampling—by means of pen recorders—is effected to an accuracy within one per cent.

Another use for radioactive isotopes applied in the United States is for judging the effectiveness of cleaning action in laundries. Cotton fabric is treated with radioactive dirt, washed with various detergents and then tested for radioactivity. A laundry laboratory where this tech-

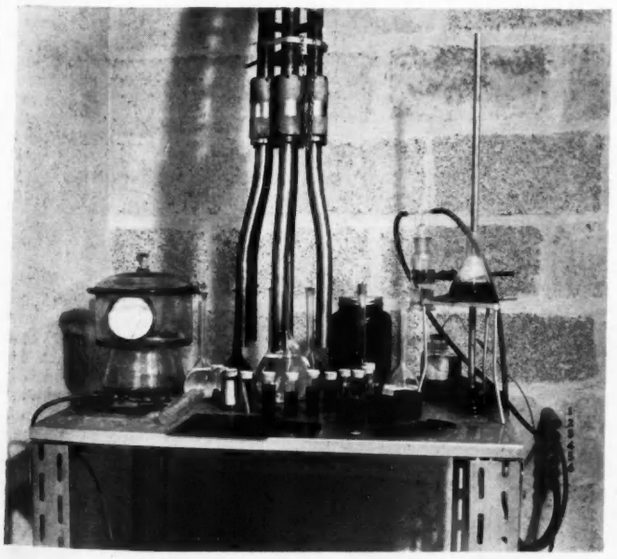

Fig. 1 Rubber and plastics can be modified by irradiation; research on this subject is being carried out in a new laboratory at the Dunlop Research Centre. The illustration shows source tubes and samples ready for irradiation.

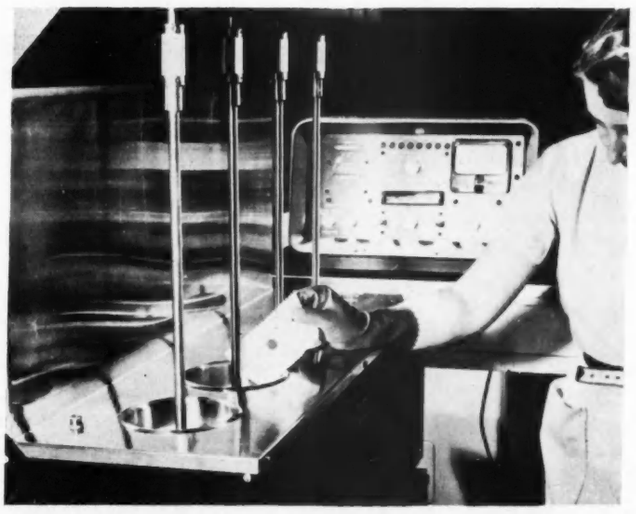

Fig. 2 Laboratory for testing the cleaning efficiency of various detergents. Cotton fabric is treated with radioactive dirt, washed with the detergents and tested for radioactivity. (Union Carbide and Carbon Corporation).

nique is carried out is shown in Fig. 2. Atomic energy workers themselves can be checked for radioactivity in the apparatus illustrated in Fig. 3. It was developed at the Los Alamos National Laboratory. The worker is rolled into the large cylindrical radiation counter and tested for radiation from products absorbed by the body from food, water and elsewhere.

Pest control can also be assisted by radiation, according to Mr. A. H. Strickland of the Plant Pathology Laboratory, Harpenden, in a paper presented before Section M of the British Association. It appears that gamma radiation has been employed to eradicate screw-worm in the Dutch East Indies and Curaçao and to sterilise male flies in parts of America. The method was, however, difficult and costly and had special dangers of its own.

In our discussion of the use of isotopes in a previous Atomic Review (August 17, page 220) we described the model ASS/53 pipeline spider made by Gamma-Rays Limited, Foundry-lane, Smethwick, 40. Unfortunately, we stated that the spider was intended to carry a cobalt source; this is not correct, and the source actually employed is iridium. A representative of the company states: " Pipe-welds are very rarely, if ever, examined by means of cobalt sources, owing to the hardness of the radiation relative to the thin wall of the pipe. The softer radiations of iridium are more suited to the effective radiographic examination of wall-thicknesses in the region of $\frac{1}{4}$ in. to $\frac{1}{2}$ in. (pipeline averages) and, in consequence, the use of cobalt is limited.

Radioactive Sources

The United States Atomic Energy Commission has recently announced reductions in the prices of two radioisotopes. They are carbon 14 and iodine 131. Carbon 14 is used in studies of photosynthesis and complex biological systems including the human body. Iodine 131 is valuable in the diagnosis and treatment of thyroid gland disorders. Its efficacy arises from the fact that almost all iodine (radioactive or otherwise) that enters the body travels to the thyroid; accurate location of the radioactive action is thus achieved. The new price for carbon 14 is 28 dols. per millicurie, as against the previous price of 36 dols., for shipments of 199 millicuries or less; for larger shipments the price will be 22 dols. per millicurie as against 32 dols. The new price for iodine 131 is 50 cents per millicurie for shipments of 499 millicuries or less and 40 cents for greater quantities. Before, iodine 131 cost 75 cents and 65 cents for similar amounts.

The Operations Division of the United States Oak Ridge National Laboratory has produced a 2,000 curie caesium 137 gamma-ray source—a quantity equivalent, according to the U.S. Information Service, to 50 million dols. of radium. The source was recovered by chemical means from reactor wastes. It was converted into dry caesium chloride powder and compressed at 20,000 lb. per sq. in. to form pellets. Three of the pellets were combined to make the final radiation source by placing them in a double-walled stainless-steel capsule. It will be used in a programme of the University of Michigan for the exploitation of fission products. An earlier caesium source of 1,540 curies is now contributing to medical research at the Oak Ridge Institute of Nuclear Studies. The Oak Ridge laboratory is operated for the Atomic Energy Commission by the Union Carbide Nuclear Company, a division of the Union Carbide and Carbon Corporation.

The future programme of isotope preparation has been described by Mr. A. F. Rupp, director of the Operations Division. A pilot plant, designed to test processes for separation of fission products from reactor wastes on a large scale, is under construction at Oak Ridge. The plant is to be put into operation next June and will then be capable of separating and packing 200,000 curies of caesium 137 a year. This offers a prospect of significant price reductions. The present cost of producing large quantities is about 14 dols. a curie, not including fabrication and special handling. In addition, large quantities of other fission products will be separated including strontium 90, cerium 144, promethium 147 and ruthenium 106.

Ideas and Speculation

Refractory metals are necessarily some of the most difficult to separate from their ores, but a new process, believed to be economic in operation, is reported to be under development in the United States. Manganese has already been extracted from rhodonite at very low cost by the process, which employs high-intensity electrical arcs. The ore is combined with from 15 to 20 per cent. of carbon to form a consumable positive electrode and, on application of an electric current, this anode is progressively vaporised. While in the hot area created by the arc, the various ore constituents are decomposed so that the pure metal can be collected. This collection may be similar in principle to the charcoal block and blow-pipe method of analysis, familiar to most schoolboy chemists. Surrounding the arc there must be a temperature gradient so that if a collector plate is situated at a particular distance from the arc, that is on a given isotherm, that fraction of the vapour which condenses at the corresponding temperature will be deposited on the plate, thus effectively separating the selected metal. Naturally, the process depends on the use of very high temperatures, of the order of 10,000 deg. C., but it is claimed that very small quantities of electricity are required, ranging from 3 kWh to 6 kWh per pound of material extracted. This economy may be partly due to the heat generated by the consumption of the carbon in the anode. It is stated that full-scale experiments are shortly to be undertaken to extract metals from their ores in commercial quantities.

Though no mention of such a connection has been made, the possible application of the process to atomic energy will be immediately apparent. Zirconium is ideal, because of its low capture cross-section for thermal neutrons and its heat-resisting, non-corrosive and easy working properties, for the cladding of solid uranium fuel elements, and as a construction material for water-cooled reactors. Its value is underlined by three contracts recently placed by the U.S.A.E.C. for the purchase of 11 million lb. of zirconium over a five-year period. Unfortunately, however, zirconium is associated in its ores with about $2\frac{1}{2}$ per cent. of hafnium, a neutron absorber which itself has nuclear applications—in control rods for example—but which defeats the low neutron absorption characteristics of the zirconium. Zirconium retains its strength at high temperatures and its melting point is 1,854 deg. C., but this, though an advantage in use, makes separation very difficult, a problem complicated by the similarity of the two metals. Originally zirconium was separated by the Kroll process—developed for producing titanium—but of the several known methods of removing hafnium, the one selected by the A.E.C. is still classified. However, it is known to be the most costly section of the six-stage process that reduces the ore to zirconium sponge. Now, new or modified hafnium separation processes promise to cut costs by as much as half. Can it be that one of these methods is the arc process described in the preceding paragraph ?

Another process is suggested by some research results published in 1954 in the Soviet Union by R. V. Teis, but which have more recently been translated (*Doklady Akad. Nauk*, U.S.S.R., vol. 99, page 585, 1954). The research concerned the water of crystallisation of sodium sulphate, sodium carbonate, calcium sulphate and barium chloride. It was found that crystals formed from a solution of a salt in water, comprising a mixture of ordinary water (H_2O) and heavy water (D_2O), contained an increased proportion of the heavy constituent in their water of crystallisation. Presumably the crystal lattices are such as to accept more readily molecules of heavy water. It follows that by means of a cyclic or cascade system, the concentration of heavy water in crystals could be continuously increased and a commercial means of separation developed. Possibly such a process may have been investigated and found wanting. Could it not, however, have been partly responsible for the Atomic Energy Authority's decision to abandon the geothermal project in New Zealand ?

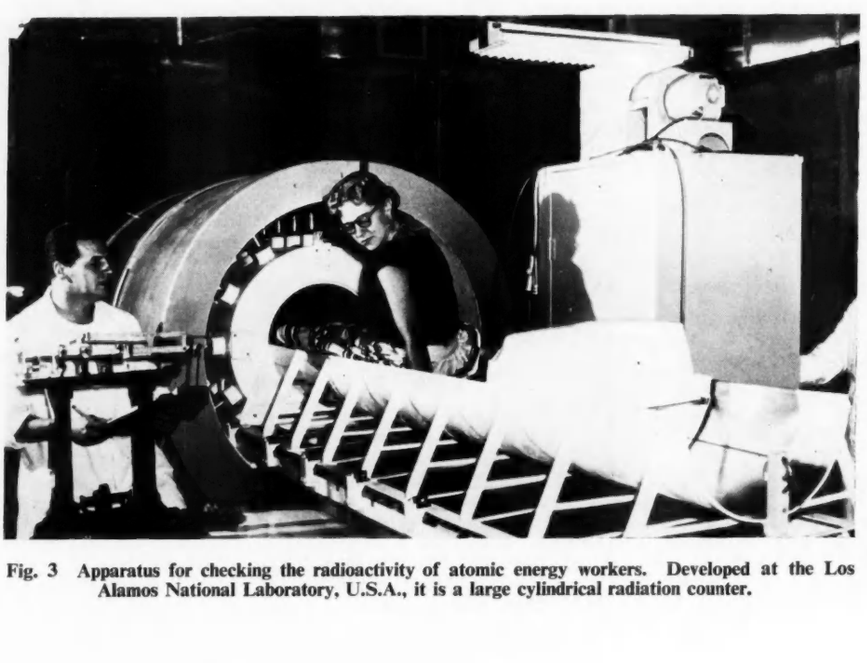

Fig. 3 Apparatus for checking the radioactivity of atomic energy workers. Developed at the Los Alamos National Laboratory, U.S.A., it is a large cylindrical radiation counter.

POSTSCRIPT

There is a story that just before the war, not long after Hahn and Strassman in Berlin first caused fission of uranium with neutrons, a very far-sighted and presumably wealthy individual had a considerable quantity of uranium ore transported to New York and deposited in a warehouse. Subsequently he became even wealthier. No doubt a similar far-sighted character is now assiduously accumulating gas mantles which consist largely of thoria.

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The Maudslay Society and the Junior Institution of Engineers, jointly responsible for the administration of the Maudslay Scholarship Foundation, announce that scholarships of £100 value have been awarded to Colin R. Evans and M. J. C. Swainston, both apprentices at the Royal Ordnance Factories, Woolwich.

QUICK-TURN TUG

The tug Sabre, which has recently been delivered to the Manchester Ship Canal Company, is the first of four specially designed to suit the particular towing requirements of the Canal and Port. It is a twin-screw Diesel tug of 97 ft. overall length, 88 ft. between perpendiculars, and 24 ft. 4 in. moulded breadth, and was built by P. K. Harris (Shipbuilders), Limited, Appledore, Devonshire, to the designs of Burness, Corlett and Partners, Limited, Basingstoke, Hampshire.

The hull of the tug is constructed on the hydroconic principle, with certain unique underwater lines. Twin rudders, together with the twin engines and the fact that the engines are directly controlled from the bridge, combine with the hull form to give the tug exceptional manoeuvring qualities. Tests have shown that the tug can turn in 1½ to 2 lengths using the twin rudders and only one engine. From full ahead speed of over 10 knots the vessel can gather sternway in 25 seconds. For ahead steering, using only one engine, only 10 deg. of opposite helm are required.

CONTINUOUSLY RUNNING ENGINES

The vessel is propelled by two 4-stroke Diesel engines made by Ruston and Hornsby, Limited, Lincoln, each engine developing 645 b.h.p. on a continuous rating basis, and 720 b.h.p. on a 12-hour basis, giving a shaft h.p. of 603 on each propeller shaft. The engines are uni-directional, and run continuously while the tug is operating: starting, stopping and reversing are by means of gearboxes. Cooling is by a closed-circuit fresh-water system, which can be pre-heated before the engines are started. For this purpose each engine is fitted with a 3kW electric heater, supplied with current from the auxiliary generators. Alternatively, the engine jackets can be heated by the cooling water from the auxiliary engines. As the main engines are normally running during the whole of the time the tug is operating, only three small air bottles are required for starting.

There are two independent auxiliary engines, each one being directly coupled to a 25kW electric generator. The engines are the 6 FRM type, made by R. A. Lister and Company, Limited, Dursley, Gloucestershire and the generators were made by Laurence, Scott and Electromotors, Limited, Norwich.

HYDRAULIC GEAR-BOXES

The drive from each main engine is taken to the propellers through a Hindmarch-M.W.D. oil-operated reverse reduction gearbox designed and manufactured by Modern Wheel Drive, Limited, Chesham, Buckinghamshire. The two gearboxes are of the manufacturers' standard No. 5 pattern, except that the normal 2 to 1 gear ratio has been altered to 2·408 ahead and 2·389 astern. These altered ratios were needed to reduce the slow-running speed of the propeller shafts to 75 r.p.m. without introducing critical speeds.

Each gearbox is fitted with two hydraulically operated brakes on the clutch shafts. These brakes come into operation automatically as soon as the main engine telegraphs are moved to the stop position. They prevent the propellers from rotating when the tug is working astern of a ship and is being dragged along with engines stopped.

The gearboxes normally operate with oil at 50 to 60 lb. per sq. in. pressure, and if this should fall for any reason, a stand-by Hamworthy gearbox lubricating oil pump, driven by a Laurence Scott 9 h.p. motor, trips in automatically to restore the full pressure. This safety arrangement ensures that there can be no failure of control over the gearboxes due to loss of oil pressure, a very important factor for a tug which has to operate in restricted waters.

The tug is designed for operation astern as well as ahead, and it is essential that ample stern pull should be provided by the propellers. This has entailed a compromise design of propeller, embodying both ahead and astern pull—an unusual feature in a tug but one which was specified as essential by the Ship Canal Company. The propellers give a compromise pull of 17 tons when pulling ahead and 10 tons when working astern. The light running speed is 10¼ knots.

The Manchester Ship Canal Company's tug "Sabre" has remarkable manoeuvring properties. There is no funnel: exhaust gases from the Diesel engines are conducted away by the lower legs of the tripod mast.

Externally, the most noticeable features of the tug are the absence of a funnel and the large wheelhouse and tripod mast. Provision of maximum visibility aft was the principal reason for dispensing with the funnel. Coupled with the design of the wheelhouse, this has been so successful that there is a completely clear view aft and only minor blockages in the whole 360 deg.

As there is no funnel, the exhaust gases have to be disposed of by other means; they are led up the lower parts of the after legs of the tripod mast, which is partly of steel, with wood at the top. It is believed that this is the first occasion on which the exhaust from engines developing 1,200 b.h.p. has been dealt with by means of a mast instead of a funnel. The design of the mast had to provide for an outlet as high above the deck as possible, and at the same time to avoid excessive back pressure on the main engines. Special louvres are formed in the forward sides of the exhaust outlets, and when the tug is travelling forward the louvres help to deflect the gases upwards. Experience has shown the design of the exhaust outlets to be completely successful, it being impossible to detect fumes on the deck whatever the direction of the wind.

The exhaust trunkings are insulated with asbestos blocks, and at the corners of the wheelhouse and where they pass through the accommodation they are quite cool. There is no noise or exhaust "drum" either on the bridge or in the accommodation. The two main exhaust silencers are in the forward end of the engine room, mounted one above the other, the port main engine exhausting to the starboard mast, and vice versa. Particular attention has been paid to the insulation of the silencers in the engine room, to keep down both noise and heat.

Complete control of the engines and gearboxes is normally exercised from the bridge through telegraph controls made by Chadburns (Liverpool), Limited, Aintree, Liverpool.

Steering is by a hydraulic-electric gear made by Donkin and Company, Limited, Newcastle-upon-Tyne, a Laurence Scott 8 h.p. motor driving the hydraulic pump. In the event of failure of this motor there is automatic warning to the engine room by means of a Klaxon hooter.

One other item of equipment which can be controlled from the bridge is the towing hook. Two of these hooks, of 20 tons each, made by Loveridge, Limited, Cardiff, are provided. They are of special design, to enable them to be controlled from the bridge.

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

LONDON
"Motor Control Gear," by W. J. Johnson. Central London Branch. White Hall Hotel, Bloomsbury-square, W.C.1. Mon., Sept. 10, 7.30 p.m.
"Fifth Electrical Engineers' (ASEE) Exhibition," film and commentary, by P. A. Thorogood. South-West London Branch. Prince of Wales Hotel, S.W.19. Thurs., Sept. 13, 8.30 p.m.

HALIFAX
"Oils and Greases," accompanied by films: "Thin Film Lubrication" and "Lubricating Grease," by Mr. G. Stott. Halifax Branch. Crown Hotel, Horton-street, Halifax. Wed., Sept. 12, 7.30 p.m.

British Colour Council

LONDON
Silver Jubilee Celebrations, Mon., Sept. 24 to Wed., Sept. 26. British Colour Council, 13 Portman-square, W.1. Reception of members and delegates. Mon., Sept. 24, 6.30 p.m. "Colour through History," by R. J. Smith. Tues., Sept. 25, 10.30 a.m., and at 2.45 p.m., "Colour over the Counter," by a panel of speakers. "Colour in Fashion," by J. Cavanagh. Wed., Sept. 26, 10.30 a.m., and at 2.30 p.m., a questions session: "Colour Appeal."

British Interplanetary Society

LONDON
"Rocket Development in U.S.A.," Overseas Lecture, by F. C. Durant III. York Hall, Caxton Hall, Caxton-street, S.W.1. Sat., Sept. 8, 6 p.m.

Incorporated Plant Engineers

BLACKBURN
"Maintenance of High Efficiencies on Economic Boilers," by I. S. Groundwater. Blackburn Branch. Golden Lion Hotel, Blackburn. Thurs., Sept. 20, 7.30 p.m.

DUNDEE
"Application of Work Study and Incentives to Maintenance," by D. Gardiner. Dundee Branch. Mathers Hotel, Dundee. Mon., Sept. 10, 7.30 p.m.

GLASGOW
"Rockets and Space Flight," by P. H. Tanner. Glasgow Branch. Scottish Building Centre, 425-427 Sauchiehall-street, Glasgow. Thus., Sept. 13, 7.15 p.m.

ROCHESTER
"Corrosion of Iron and Steel and Remedial Measures," by F. S. Bricknell. Kent Branch. King's Head Hotel, High-street, Rochester. Wed., Sept. 19, 7 p.m.

CHESTER
"Industrial Pneumatics," by F. X. Kay. Merseyside and North Wales Branch. Stafford Hotel, City-road, Chester. Thus., Sept. 13, 7.15 p.m.

NEWCASTLE-UPON-TYNE
"Light for Industry," by R. J. Fothergill. North East Branch. Roadway House, Oxford-street, Newcastle-upon-Tyne. Thurs., Sept. 13, 7 p.m.

BRISTOL
"Ventilation and Air-Conditioning," by J. R. Kell. Western Branch. Grand Hotel, Bristol. Wed., Sept. 12, 7.15 p.m.

Institution of Engineering Designers

LONDON
"Function, Appearance and Production—Three Angles on Good Design," by L. Bruce Archer. 38 Portland-place, W.1. Thurs, Sept. 13, 6.45 p.m.

The address and Telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. (LANgham 5927.)
British Colour Council, 13 Portman-square, London, W.1. (WELbeck 4185.)
British Interplanetary Society, 12 Bessborough-gardens, London, S.W.1.
Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institution of Engineering Designers, 38 Portland-place, London, W.1. (LANgham 8847.)

THE HUMAN ELEMENT

Disturbance in the shipbuilding industry—High annual gain in Volkswagen productivity—Dock unions' conflict—First things not first.

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A Strike for Security

Shipbuilding craftsmen on the Clyde have withdrawn their labour to support a demand not for higher earnings but for greater security. The struggle is likely to be prolonged and bitter. It may spread to the Tyne and other shipyards. The "black squad" workers, as the men are known, are the elite of the skilled in the industry. They have, from time immemorial, worked on a piece-rate system which currently yields most of them £20 a week or more. Yet the present time rate of payments would bring them less than £9 for a 44 hour week. It is this gap which the United Boilermakers' Society, to which the men belong, are determined to narrow. They are asking a guaranteed wage packet of £14 7*s.* 6*d* for welders and caulkers and £13 5*s.* 6*d.* for platers. The time of high prosperity and full order books is, they say, the right time to bargain for a revision of the wage structure. Other unions—and they clearly have in mind the car-workers' unions—have been caught unawares.

The employers will not admit the principle of a high time rate of pay, nor that of the guaranteed week. Presumably they fear that the granting of the union's demands will spark off similar demands from other grades, who do not have the same yawning gap between what they can earn on a time rate basis and what they do earn on piece-work. Also, probably, they fear that many of the black squad men would gladly fall back on £13 to £14 a week and not bother to work as hard as they are working now. In fact—since the wage demand is based on an hourly rate—the employers fear that the men will work slowly, making overtime necessary, and will take away an even larger sum for doing comparatively little. Hence the employers' contention that the granting of high time rates and the admission of the principle of a guaranteed week would slow down the rate at which ships are being built and further swell shipbuilding costs.

The background of it all is an atmosphere of mutual distrust. The relations of management and labour are bad, probably worse than in any other metal-using industry. The issue has been through all the steps of the negotiating machinery available. The boilermen describe themselves as "a militant union" and are not party to any agreement on arbitration. The likelihood, therefore, is of a fight to the finish, at a frightening cost to the employers, the men and the country. The bitterness is such that neither side wants even the Ministry of Labour to attempt a solution.

The feeling of the onlooker is that the whole affair is distressingly unnecessary. One hundred ships worth £45 million are building on the Clyde. Orders for nine more tankers were booked last week. The situation is similar on the Tyne—where black squad men are expected to strike this week-end—and elsewhere. Mr. Niarchos was quoted recently as saying that the oil carriers could not think in terms of round-the-Cape tankers as the world capacity for tanker building is barely adequate to provide replacement tonnage and cater for normal rising demand. The British merchant fleet is old and modern ships are necessary to operate world routes at a profit, even more so to compete successfully when the volume of trade falls off. Never has the outlook for the British shipbuilding industry been brighter.

There is a good *prima facie* case for the boilermen's demands. The gap between earnings possible on time and piece rates is far too large. The demand for security is a moderate one; recently, the word "guaranteed" has been tied more to annual than to weekly earnings. Nothing in the men's demand prevents employers from sacking redundant personnel. On the contrary it would make sacking more necessary, and would in fact achieve what other industries have been trying to do with wholehearted Government encouragement and support. The real issue is one of good faith. Would the men work less if they were not dependent on payment by results? A good many leading industrialists would say the reverse is more likely. Perhaps a salutory step would be for one of the companies to give the men's idea a trial. Within a few weeks 40,000 workers in the shipbuilding and allied trades might well be idle.

This tragic development with both sides equally determined—almost fanatically so—could seriously lower the prestige of British shipbuilding in the eyes of all shipping nations. The case for a development council for the industry, on which would sit fair-minded and experienced industrialists from other fields, has never been stronger. Apart from this deplorable strike, the country has a right to know why it is that British shipyards allegedly take twice as long to build a ship than Japanese or German yards. Full order books and the high quality of the work cannot be the whole of the answer.

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Productivity in the Volkswagen Works

The detailed statistics of production and employment given in the annual report of Volkswagenwerk G.m.b.H., Wolfburg, reveal a staggering increase in output per worker over the past four years. The figures are as follows:

—	Output		Employment	
	Number of Units	Index	Total	Index
1952 ..	46,881	100	17,381	100
1953 ..	68,754	147	20,569	118
1954 ..	108,839	232	25,283	147
1955 ..	177,657	380	31,570	182

Thus, in 1952, 2·7 vehicles were produced per employee; in 1955 this number had risen to 5·6. On this basis the average annual gain in productivity amounts to 27½ per cent.

Certain aspects of the company's progress will doubtless be of considerable interest to British workers. The company's sales performance speaks for itself. In 1955 they accounted for 42 per cent. of total car production in Germany and for over 48 per cent. of total German car exports. The proportion of the value of output exported in that year was 45 per cent. Information in respect of 1956 shows that exports have continued to increase both in absolute and relative terms. During the summer the company decided to limit the proportion of cars exported to half the output in order not to lose ground on the home market to companies less successful in export markets.

The policy of Volkswagen is well known—the choice of a rugged, ugly, slow cylinder speed, weatherproof car, their adherence to a standard model and a pugnacious, relentless sales drive throughout the world.

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Dock Unions' Private Fight

The Trades Union Congress are being asked to help the National Amalgamated Stevedores and Dockers and the Transport and General Workers' unions to find a *modus vivendi*. The motion has been tabled by the N.A.S.D., who are still smarting from their suspension from membership of the T.U.C.—later rescinded—for poaching nearly 10,000 T. & G.W. members in northern ports. After a six-week strike for recognition, in which nearly 20,000 dockers were involved, the little union's leaders agreed to accept the jurisdiction of a T.U.C. disputes committee and to expel their northern members. They did so, but one of the men challenged the expulsion in the courts and obtained a decision that his expulsion was not legal. There took place subsequently a number of meetings between the two unions without any agreement being reached.

The present position is that the N.A.S.D. still have their northern members, to whom they say they must give service and for whom they are attempting to get representation on the negotiating committees. The months of inactivity—from the time the N.A.S.D. expelled their northern members until the validity of the expulsions was successfully challenged—have caused a large number of them to leave the union, and others to build up arrears of subscriptions. There has not, however, been a corresponding flow back into the T. & G.W. The latter allege that the officers of the N.A.S.D. continue to solicit new members and that they have tried to restore their membership. Tempers are rising and another head-on clash cannot be long deferred.

The T.U.C. General Council will ask unions to alter their rules to legalise expulsions made on the instruction of a T.U.C. disputes committee. But this is unlikely to end the conflict. Its root cause—the apparent inability of the T. & G.W. to cater for their members' needs where stevedores and dockers are concerned—will not be removed so easily.

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Call to Work Harder

In a recent letter to *The Times*, the Rev. J. C. Vaughan Wilkes, of Leeds, writes:—

"I live in a place where—at present—40 hour weeks and redundancy are distant possibilities, not live issues. Pretty well all the people in my parish and its neighbours are working six (sometimes seven) days a week and working 'over' .... I confess to some impatience with the critics of our labour force who urge that it work harder ... Indeed in our part of the world many men (and women) are working much too hard."

Mr. Wilkes ends his letter with a reference to the widely accepted, but in his view dangerous, basis for the call to work harder—namely a rising standard of living which is taken to mean "more money and material possessions." We are exhorted to raise this standard of living higher and higher. From the utterances of cabinet ministers and trade union leaders alike little else would seem to matter. No other motive is admitted as a worthwhile incentive to give one's best. Mr. Wilkes has found both support for his views and opposition to them. His opponents do not question the length of the hours worked but the amount of work done during them. Yet conversations with some of the leading industrial concerns in Britain reveals that fatigue from overwork is one of the main problems of a well-managed company. Left to themselves in a well run factory where energy is not expended in conflicts between workers and the management, the workers' tendency is to burn themselves out, by working too interestedly and too long. Tnis has been said by the heads of companies whose employees are on a time-rate as well as of those who pay by results.

The serious implications of such statements are perhaps not obvious, except that slackening is almost invariably a by-product of bad management. The danger of over-work, of the compulsive need to work harder, is a basic unbalance in one's interests and a narrowing of human vistas. It implies an erosion of social functions in man, accelerated by passive leisures, such as watching television, that fit well into a tired and listless state. What few will admit is that it is the Achilles heel of a democratic society. Perhaps the spread of automation will reverse the trend, perhaps the unions will succeed in reducing working hours and eradicating "the overtime habit." If they do not, we may all be the poorer for our wealth.